Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

R31
Cop. 2

ARS-72-76
December 1969

PROCEEDINGS OF THE CONFERENCE OF COLLABORATORS

FROM SOUTHERN AGRICULTURAL EXPERIMENT STATIONS

U. S. DEPT. OF AGRICULTURE
NATIONAL AGRICULTURAL LIBRARY
MAR 13 1970
CURRENT SERIAL RECORDS

Held at New Orleans, La.
March 24 and 25, 1969

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

The Conference on Progress in Research to Help Cotton Meet the Challenge was held on March 24 and 25, 1969, in New Orleans, La. This conference was sponsored by the Southern Utilization Research and Development Division in cooperation with the Southern Agricultural Experiment Stations. Its purpose was to strengthen liaison between the Southern Utilization Research and Development Division and the Experiment Stations, and to exchange information on important subjects of joint interest.

This publication reports the statements presented by the various speakers during the conference.

The opinions expressed by the participants appearing at this conference are their own and do not necessarily represent the view of the U.S. Department of Agriculture.

Underscored numbers in parentheses refer to references at the end of each paper. The data presented in the references, figures, and tables are reproduced essentially as they were supplied by the author of each paper.

Mention of companies or products used in this publication are solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned.

CONTENTS

J. W. Sites, General Chairman *Page*

Welcome
C. H. Fisher 1

Research coordination
L. E. Hawkins 2

USDA Processing and utilization research in the South
F. R. Senti 5

The impact of the cotton research committee of Texas on the future of cotton
C. Cox, Jr. 9

SESSION I: D. Chambers, Chairman
Breeding of new glanded varieties of cotton (Summary)
J. W. Neely 12

Breeding of glandless varieties of cotton
R. J. Miravalle 13

Research in agricultural economics at the Delta Branch Experiment Station (Summary)
W. K. Porter, Jr. 16

Innovations in the ginning of cotton (Summary)
V. P. Moore 17

SESSION II: J. W. Weaver, Chairman
Mechanical Processing of Cotton
CPI Research—1968/1969
G. S. Buck, Jr. 18

Fabric structure and its relation to durable press properties
G. J. Kyame, G. F. Ruppenicker, Jr., and H. W. Little (Presented by G. J. Kyame) 22

The influence of yarn parameters and weave variants on the durable press properties of fabrics
G. F. Ruppenicker, Jr., G. J. Kyame, and H. W. Little (Presented by G. F. Ruppenicker, Jr.) 30

Durable press cotton fabrics woven from polymer-sized yarns
J. T. Lofton, R. J. Harper, H. W. Little, and E. J. Blanchard (Presented by J. T. Lofton) 39

Chemical Finishing of Cotton
Preparation of flame retardant cotton products (Summary)
J. V. Beninate 47

Mild cure finishing process for the production of wrinkle-resistant cotton fabrics
R. M. Reinhardt, N. A. Cashen, and J. D. Reid (Presented by R. M. Reinhardt) 48

Pre-cure durable press finish through the use of polymer deposition
H. H. St. Mard, C. Hamalainen, W. A. Reeves, and A. S. Cooper, Jr. (Presented by H. H. St. Mard) 53

Basic aspects of the crosslinking of cotton
S. P. Rowland 54

SESSION III: J. J. Mikell, Chairman

New application of yarn mercerization in cotton fabric finish (Summary)
C. M. Welch, A. L. Murphy, and M. F. Margavio (Presented by C. M. Welch) 61

New flame retardant cotton batting products
N. B. Knoepfler 63

How are fiber blends affecting cotton's markets?
H. G. Kennamer, Jr. and T. L. W. Bailey, Jr.
(Presented by H. G. Kennamer, Jr.) 75

Economics of growing cotton vs. other crops
P. L. Strickland, Jr. 85

Discussion 92

Attendance list 94

PROCEEDINGS OF THE CONFERENCE OF COLLABORATORS FROM SOUTHERN AGRICULTURAL EXPERIMENT STATIONS, HELD AT NEW ORLEANS, LA., MARCH 24 and 25, 1969

J. W. Sites, *University of Florida, Gainesville, General Chairman*

WELCOME

by

C. H. Fisher, Director
Southern Utilization Research and Development Division
New Orleans, La.

It is my distinct privilege and pleasure to greet this excellent audience of the 28th Annual meeting of the Collaborators from the Southern States and Puerto Rico.

We in the Southern Utilization Research and Development Division look forward eagerly to these annual meetings with our friends from the Southern Experiment Stations. We prize the opportunity of discussing research with you. In addition, we enjoy—in a personal way—the conferences and associations with our colleagues from the States.

We have an unusually important topic this year and a splendid program. Most of the talks are concerned, naturally, with cotton. A few of the talks are of broader interest.

We are particularly fortunate because Louis E. Hawkins—a highly competent and admired leader in agriculture—will tell us about cooperation in agricultural research.

We are now in our new building, which houses two pilot plants: one for the mechanical processing of cotton and the other for the chemical processing of cotton. Our new laboratories, located in the old building, are completed and ready for use. We are grateful, of course, for the new and useful facilities which will make it easier for SURDD to do research.

The Textile and Clothing Laboratory, located at one time at Beltsville, Md., is now a part of our Southern Utilization Research and Development Division. The work of the Textile and Clothing Laboratory is particularly well known to home economists. This Laboratory, located on the University of Tennessee Campus, is being operated in cooperation with the University. Ben M. Kopacz, Acting Chief, is doing a splendid job directing the affairs of this Laboratory.

Our scientists, engineers, and supporting staff continue to be highly productive. Our research progress last year is described in 45 patents and almost 300 publications. I wish to thank the members of our staff for their productivity and dedication.

Industry continues to adopt and use our research. There are a number of such instances for the past year. We are grateful for industry interest in our work and cooperation that resulted in the commercial use of some of our research.

I hope the Conference will be a great success and that your participation in it will be rewarding and enjoyable.

I wish to express thanks to the many individuals contributing to the success of our Conference. Among these are:

General Chairman, John W. Sites; session chairman, Doyle Chambers, J. W. Weaver, and J. J. Mikell; Doyle Chambers and J. J. Mikell for special assistance in planning the Conference; our speakers for bringing us helpful and interesting information; our researchers for their valuable work; other members of SURDD for their supporting activities; and our audience—we could not have a conference without an audience.

RESEARCH COORDINATION

by

L. E. Hawkins, Director-at-Large
Southern Region
Agricultural Experiment Stations
Oklahoma State University
Stillwater, Okla.

The advanced position of the United States of America in agriculture, industry, commerce, national defense, the professions related to human health and well-being and, indeed, the achievement of what has come to be known as the affluent society is the result of the application of science and technology to the production and distribution of those things that meet the wants and needs of people. The development and growth of a meaningful culture through such means as sports, entertainment, the arts, and literature are most essential to the more excellent life; but food, raiment, shelter, and transportation come first in any people's life of priorities. Thus, as these basic material needs are met to a fair degree of adequacy, the essential elements of culture are made possible in the time and effort remaining for the building of cultures.

The fantastic progress of production on the farm and ranch in this country is indicative of the fabulous advancement in all areas of agriculture in the past two decades. We thought a few years ago when the farmer produced the food requirements for himself and ten others he was challenging the feat of Atlas himself, the superman of Greek mythology, who bore the weight of the earth on his head and shoulders. Then that number grew to 30, and now 40, and will certainly be 50 or even 60 in the near future. The point of emphasis here is that the number of mouths which one farmer is said to feed has become quite meaningless as a number. The many industries and trades that have come into the picture between the farmer and the consumer of food and fiber have become essential forces in getting the crop grown and harvested, and in getting the finished product into the hand of the consumer.

The total fraction of the national labor force, estimated at 40 percent, which finds its employment and livelihood directly or indirectly in agriculture and related industry and commerce, continues on with but little shift or change as science and technology are applied to this complex job. Fewer farmers and ranchmen are required on the land, but more tradesmen and handlers are required to provide the farmer with equipment, supplies and materials, and to process and distribute the produce of his farm to the consumer of food and fiber.

Lest I seem inconsistent here with respect to my earlier comments—that the application of science and technology to production of food, raiment, shelter, and transportation has left time and effort available for those things and activities which make for a richer culture and a more affluent society—let us remember that the total labor force is growing steadily. The brains, hands, and resources to make, supply, and provide those items of culture and the good life are increasing steadily, and these are *not* absorbed in the food and fiber business as is true in many lands where the wolf of hunger is at the door.

Agriculture, directly and indirectly, accounts for a third of the total commerce of the United States. Agriculture is so vital to the national economy that its solvency must be guarded and protected else the national economy will crash again as occurred in 1929. That catastrophe was the culmination of 10 years of an ever tightening cost-price squeeze on agriculture. Such a tragic fate is not seriously threatened in the 1960's, we hope and trust. Three vitally important factors must be observed and attended, however, else a crash will be inevitable. These are (1) research and education, (2) adequate and wisely managed credit, and (3) a more effective means of farm bargaining power than seems available at present. Permit me to discuss only the first part of the first one of these three factors, namely research, in the few minutes available to me here today.

The magnitude of the total research program associated with agriculture and related industry and commerce presently runs about $1.1 billion annually. The key figure there is 11. $1,100 million is the cost of operating research programs, public and private, in support of agriculture nowadays—directly and indirectly. A little over one-half of this program is performed by industry and slightly less than half is done by Federal and State agencies. I said 11, six for industry and five for the public agencies. Now,

of the $500 million a year program performed by public agencies, Federal and State, the State agricultural stations perform about 60 percent of the $500 million cost and the United States Department of Agriculture about 40 percent of this public agency part of the total agricultural research program.

Now, an annual program costing $1.1 billion a year is, in fact, of course, a large program, but it is modest in terms of the value of the total product of the business which is served by this research. Gross farm income from all sources now runs close to $40 billion a year. A $1.1 billion research program equals but 2-3/4 percent of the value of the farm produce, therefore. Many aggressive businesses, particularly industries with new consumer products—and agriculture has many new products and needs more —invest up to 10 percent of the gross sales in research.

Let us get more definitely into this matter of research coordination, which is the subject of my discussion. Four years ago the Director of Science and Education, U. S. Department of Agriculture, proposed to the Experiment Station Committee on Organization and Policy (ESCOP) that a study of total public agency agricultural research be made, and a long range program or research be projected to extend over 10 years in the future. Nyle Brady was then Director of Science and Education and I was Chairman of ESCOP. The proposal was brought about in part by a request of the Agricultural Subcommittee of the Senate Committee on Appropriations. ESCOP reacted favorably to Dr. Brady's proposal and moved promptly to get the authorization and backing of the Executive Committee of the National Association of State Universities and Land-Grant Colleges. Dr. Brady likewise prevailed upon the Secretary of Agriculture, and the Secretary and the Chairman of the Land-Grant Executive Committee directed that the study be made.

The Executive Committee authorized ESCOP to handle the matter on behalf of the Land-Grant Association, and the Secretary assigned the Federal responsibility to the Research Program Development and Evaluation Staff (RPDES) under the Director of Science and Education. An appropriate Federal-State joint task force was set up immediately and the study was under way within a month of the time of Dr. Brady's proposal to ESCOP.

That joint task force drafted numerous well-informed individuals and subtask forces, and literally moved mountains of resource information in the ensuing months to arrive at a reasonably accurate inventory of then current agricultural research, and to envision and project a 10-year program ahead. All of you are acquainted with the publication under date of October 1966 which documents that inventory and program. It is officially titled. "A National Program of Research for Agriculture," and is commonly known as the "Long Range Study (LRS)."

The Long Range Study, as made and published, took cognizance in the inventory of all publicly and privately funded and performed research related to agriculture, but confined attention to public agency research in the expansion over the 10 years through fiscal 1977. The report was extensively and elaborately detailed as to subject categories called Research Problem Areas (RPA's), and measured in a quantity unit called a scientist man year.

The entire program, as envisioned and published in October 1966 and projected through fiscal 1977, was combined as to Federal and State effort. Subsquently, Federal and State components were separated in terms of scientist man-years, recognizing, however, that the activities of these two sets of public agencies would have to be coordinated for most effective use of manpower, money, and other resources for productive research effort.

Now let us get at the mechanism for achieving coordination of planning among the State Agricultural Experiment Stations and by State and USDA agencies. The Agricultural Research Planning Committee was formed concurrently with but separately from the joint Federal-State task force which developed the Long Range Study. This Committee, known as ARPC, is composed of Federal and State personnel and serves well as a sounding board to firm up items of common interest and to clarify matters involving or needing close working relations of Federal and State agencies.

The State Agricultural Experiment Station Directors expected to continue to function through ESCOP and appropriate subcommittees of ESCOP, but recognized a need for a small number of full-time people working for the state station director in the coordination of effort among the states and with USDA agencies. To meet this need, each of the four regional groups of station directors established a regional position and employed a man to fill it. These four men, including myself for the South, are referred to as regional directors. Our functions and duties are numerous but mainly are to assist the State stations in cooperative effort across State lines, and to work continuously in liaison with USDA administrators for effective coordination of State-Federal research planning and effort.

A ten-man Federal-State joint task force was shaped up on a continuing basis to deal with allocations of scientist man-years by research problem areas and subareas, and with other aspects of Federal-State cooperation. The chairman of ESCOP and the four regional directors made up the State component and five administrators of USDA research agencies, the Federal segment of this joint task force. The Director of RPDES serves as chairman of this group. The body has been "legalized" as a subcommittee of ARPC.

Thirty-two ad hoc special task forces consisting of 10 to 14 Federal and State professional people, with consultants from industry and other branches of government, were established to conduct in depth studies and project expanded research programs for 32 subject areas. These programs were envisioned as National in scope to be performed by the U. S. Department of Agriculture and the State experiment stations. They were planned to extend through fiscal 1977, consistent with the Long Range Study. Most of these task forces have completed their work. Reports of this monumental effort are now in process of distribution to Federal agencies, State stations, industry, and other potential users. The recommendations of these task forces have been included in considerations of the subcommittee of ARPC regarding SMY allocations to subject area, and other related matters.

The recount and recap of these activities of the past 4 years have been reviewed for you mainly to emphasize that there is a mechanism for coordination of public agency research in the agricultural sciences. It is true that use of the mechanism by the State stations and by the USDA agencies is voluntary. It can be no other way but voluntary and by mutual consent and agreement. Active and effective cooperation by, between, and among autonomous forces, by nature of authority, can be no other than voluntary, and must be characterized by mutual desire and enthusiasm. The committees and task forces described in the foregoing discussion function in advisory capacity always. The State Experiment Station Directors, severally and separately, administer programs and manage resources within their respective States. Likewise, duly authorized administrators within USDA bear full and undiluted responsibility and authority for operations within their respective agencies.

A hopeful and optimistic look ahead will be appropriate in closing these remarks. There is need for more, not less research, in the interest of agriculture in the years before us. Consumers have become selective in choice of products, and the trade demands commodities which can be converted into salable products. Growers, processors, and other elements of the trade are keenly aware of the essential character of research. In terms of priority, our research to improve quality and increase versatility of product to the consumer, at the same time raise the level of efficiency and reduce the cost of production, processing, and handling will continue high with those forces of the National economy who are affected by the research.

A second category of research is coming to be more in demand in our so-called affluent society. The rather nebulous label, "people research," has been applied to it, but that covers quite a multitude of economic, social, and cultural sins and inadequacies. Causes of poverty, which I would rather label as employment opportunity, is one. Contamination of soil, water, and air is another. Development of recreation facilities and programs is one. Still another is selection of food stuffs to alleviate hunger and achieve adequate human nutrition. This entire category of research is more sought after than at any time in the past.

The third and remaining broad category of research in our public agency programs is the conservation, management, and use of natural resources. This subject area was prominently spotlighted in the 1930's in time of deep economic depression. Effective use of the advantages gained through conservation proved a life saver during the war years of the 1940's, and continued wise use of natural resources is recognized in the '50's and '60's as basic to a vigorous economy. We can be certain that this will continue to be a vital, productive field for research.

And so, my friends, we shall continue to be in business for all time in the future. We shall revise and adapt research programs continuously to meet needs and opportunities as they arise or can be anticipated; not our needs and desires, but the needs of our constituents, the people who make use of the products of our research. We have the mechanism for joint planning of research that will yield largest returns on investment of personnel, fund, and facility resources. We have established close and effective working relations with industry. I hope and trust that we, in the two great categories of public agency research, the U.S. Department of Agriculture and the State Agricultural Experiment Stations, will exercise the common gumption needed to join hands more closely and systematically in mutual interest and opportunity for greater success in our research effort.

USDA PROCESSING AND UTILIZATION RESEARCH IN THE SOUTH

by

F. R. Senti, Deputy Administrator
Nutrition, Consumer and Industrial Use Research
Agricultural Research Service, USDA
Washington, D.C.

It is indeed a pleasure for me to again participate in a conference of the collaborators from Southern Agricultural Experiment Stations. I hope you share my enthusiasm for these meetings which give us an opportunity to review accomplishments and discuss research of common interest as they relate to the important problems of this agricultural area. Today, I would like to discuss with you the ARS program of research on the utilization of agricultural commodities in the South, particularly as it relates to the establishment of our new Southeastern Agricultural Research Laboratory at Athens, Ga.

Except, perhaps, for those who are serving as collaborators for the first time, this group is acquainted with the program of the Southern Regional Research Laboratory. There were three other Regional Research Laboratories established for utilization research on agricultural commodities at the same time as the Southern Laboratory. These are the Northern at Peoria, Ill.; the Western at Albany, Calif.; and the Eastern at Wyndmoor, Pa. These now are the headquarters for four Utilization Research and Development Divisions. Twelve smaller field stations are part of these Divisions. The Southeastern Regional Research Laboratory will be the headquarters of the fifth Utilization Research and Development Division.

The broad objective of the research conducted in these Divisions is the development of new and improved products and processing technology that will enhance utilization of farm commodities for food, feed, drugs, textiles, industrial chemicals, and other product use. As a part of this program, research is conducted in two areas which are currently of considerable interest and importance. The first is that of health and safety as related to agricultural products. The health area can be illustrated by the health-related problems of tobacco and by the problem of harmful molds and bacteria and their associated toxins in agricultural products. An example in the safety area is the need to develop flame-resistant fabrics for garments, bedding, draperies, and other uses in order to protect the lives of our people.

The second area currently receiving much attention is that of environmental pollution. In this area we are giving increased effort to development of processing technology for agricultural commodities which will minimize waste formation, reduce water usage, and utilize waste products that would otherwise contribute to environmental pollution.

Commodity assignments to the Southern Utlization Research and Development Division (SURDD).—Each of our Divisions is assigned agricultural commodities for which it holds responsibility for conduct of utilization research. In certain cases, responsibility for a commodity may be divided between two Divisions. Generally, this reflects the importance of the commodity to the economy of the respective regions and problems peculiar to the commodity in those regions.

Among the crops on which research is conducted by SURDD are cotton, cottonseed, citrus, and other fruits, peanuts, rice, cucumbers, sweetpotatoes, sweet sorghum, and pine gum.

Research on citrus is conducted in our Fruit and Vegetable Crops Laboratory at Winter Haven, Fla., one of the field stations of SURDD. Cucumber and pickle research serving the entire industry is located at the North Carolina State Experiment Station at Raleigh. Pine gum research is conducted in our field laboratory at Olustee, Fla. Another SURDD field station of the Southern Division is located at Weslaco, Tex. Here research is carried out on problems important to the Southwest as related to fruits, vegetables, and development of sweet sorghum as a sugar crop.

Many valuable contributions to Southern agriculture and to the economy of the Nation have come from the research of SURDD. There is not time to discuss these accomplishments here. They make an interesting and impressive list and are reviewed in their publications.

Cotton is the most important crop of the South and greatest research effort has been placed on this commodity in the program of SURDD. Despite improvements made in cotton properties and processing

through research, cotton faces increasing competition from the synthetic fiber industry and even greater research effort is needed if cotton is to maintain its position in the market in face of that competition. Cotton's properties must be improved and processing costs must be reduced. Consumer needs and demands must be anticipated in fabric properties such as we have recently witnessed in durable press and the stretch-type fabrics and as can now be foreseen in flame-resistant fabrics. These objectives can only be accomplished by an aggressive research and development program. Needless to say, production research aimed at reducing cost of cotton also is essential in meeting the competition.

Research needs of farm commodities that I have illustrated with cotton, also face other farm commodities. These needs were considered in the development of the Long Range Study of Agricultural Research made in 1966 in which problems were identified and estimates were made of the scientific manpower requirements to attack these problems. To implement the expanded utilization program identified in the Long Range Study and accommodate the increased scientific staff projected in that Study will require use of all the new facilities, including the new Southeastern Laboratory, that have recently, or soon will be completed.

Southeastern Agricultural Research Laboratory.—Funds for construction of facilities for the Southeastern Agricultural Research Laboratory (SEARL) were provided in the Agricultural Appropriation Bill for fiscal year 1964. For this purpose, $9.5 million was provided. In the same Appropriation Bill, additional funds were provided for expansion of facilities of the four existing regional laboratories, $4.5 million at the North, and $1.5 million each at the South, West, and East.

In January 1967, construction of the SEARL was started. Because of time that had elapsed since original plans were made, construction costs had increased, and in FY 1968 the Congress appropriated $1.2 million to meet construction specifications for the original plans. The building will be completed and ready for occupancy this spring.

The building has 10 stories, 8 above ground. In addition to laboratory space for chemical and biochemical research, there is space designed for pilot-plant operations and an area specially equipped for pharmacology research. At the front of the building and beneath ground level is an auditorium that will seat the entire staff, a facility which our other regional laboratories lack. When completely staffed, the facility will house 460 people. The building has space designed for library facilities.

Crops important to the Southeastern states have been assigned to the Laboratory. These include fruits, vegetables, and tree nuts; animal products, with particular emphasis on poultry products and pork; feeds and forages, particularly the Southeastern grasses—Coastal bermuda, bahia and pangola; and sunflower, peanuts, and other Southeastern oilseeds.

Organization and staffing.—The staffing of SEARL will differ somewhat from that of the existing four regional laboratories in that we plan to have scientists from our Farm and Marketing Research Divisions stationed at the Laboratory to make more effective coordination and cooperation between production, processing, and marketing research on the various problems. We hope to develop relationships with the State Agricultural experiment stations under which State scientists may be located in the Laboratory to conduct research of mutual interest.

Within the Agricultural Research Service, we anticipate that there will be scientists from the Agricultural Engineering Division, Crops Research Division, Entomology Research Division, Soil and Water Conservation Research Division, Animal Husbandry Research Division, Market Quality Research Division and Transportation and Facilities Research Division in addition to the staff of utilization scientists. Perhaps 20 percent of the staff may be scientists from those Divisions. As with our other four Regional Research Laboratories, there will also be economists from the Economic Research Service stationed at SEARL.

Research of the Southeastern Agricultural Research Laboratory will be organized into seven research laboratories. These are:

1. Fruit and Vegetable Laboratory.
2. Animal Products Laboratory.
3. Forages and Feed Laboratory.
4. Biochemistry Laboratory.
5. Pharmacology Laboratory.
6. Engineering and Development Laboratory.
7. Product Evaluation Laboratory.

Each Laboratory will be headed by a Laboratory Chief who will report to the Director of the Southeastern Agricultural Research Laboratory.

Research Program at SEARL.—A few comments on each of the commodity areas and their importance to the Southeast, and more generally to the South, may be of interest.

Vegetables.—Vegetables processed in the South (South Atlantic and South Central States) in 1967 had a farm value of $63 million and a retail value of about $380 million. Processing volume over the past 20 years has increased, but major part of the farm production of vegetables still goes for the fresh market.

Several USDA and State Agricultural Experiment Station feasibility studies have shown that additional processing plants could be operated profitably when tailored to particular locations and operated on several vegetable crops to provide a maximum processing season. Future expansion of the vegetable growing industry in the South would appear to be largely dependent on expanded processing operations. Lower cost processing requires further mechanization of production, harvesting, and handling, and the development of new varieties and of new processing technology. We think that vegetable research in the Southeast and South, and this includes that of the State Agricultural Experiment Stations, should aim to bring about the following expansion of the industry in the South by 1980:

1. Increase the percentage of the vegetable crop that is processed in the South to the present (1966) National level; that is, to 46 percent of the crop from the present 16 percent of the crop.
2. Concurrently, by increased processing, to increase the vegetable crop in the South by 50 percent. This is the same increase that is projected for the total U.S. crop by 1980.

It is planned that our vegetable research group at the North Carolina State Agricultural Experiment Station will become part of the SEARL organization but will remain at its present location.

Fruit Processing.—A major deciduous fruit crop of the Southeastern States is peaches, where they have been grown primarily for the fresh market. In recent years, Short Life disease has markedly decreased peach production, particularly in Georgia. This resulted in a vigorous research program by ARS and the State Agricultural Experiment Stations which is producing new high-yielding peach varieties that have longer production life and are better suited to mechanical harvesting. Large increases in production of peaches for processing are anticipated. For example, in South Carolina, the 1965 production of peaches was 7.5 million bushels; in 1970 this will have increased to 11 million bushels and, in 1980, production is estimated to reach 14.2 million bushels. A recent study indicated that 50 percent of the canned pack of Southeastern peaches graded substandard in quality, 1 percent were grade A, and the remaining 49 percent in grades B, C, and D.

Research is needed to adapt processing methods to the existing peach varieties and to adapt it to the varieties in the new plantings as they come into bearing.

Our Fruit and Vegetable Laboratory at Winter Haven, Fla., will become part of the SEARL organization to bring together, under common direction, all fruit and vegetable research in the region.

Poultry and animal products research.—About 85 percent of U.S. broiler production, which has a farm value of $1.4 billion, is located in the South Atlantic and South Central States. Hence, this industry makes a substantial contribution to the economy of the Southern region. Several research areas would receive emphasis at SEARL. Some pressing problems on which research would be undertaken include the development of improved systems for recovery and utilization of inedible wastes from poultry processing. Magnitude of the problem is indicated by the datum that for the birds slaughter in 1967, the sewage was equivalent to that from a city of 2-1/2 million people. Large volumes of water are used and there is need, not only to minimize the cost of waste disposal, but to recover water in usable form.

Other research areas, which I shall not expand on, are the control of harmful microorganisms including Salmonella in poultry products, and the development of cooked, or partially cooked, processed food products to enlarge markets for poultry products.

It is also planned to initiate a research program on red meats with emphasis on pork and pork products.

Forage research.—Forage research will be an important program at SEARL. The Southern States are deficit in forage and feed production to support their growing livestock and poultry production. Research which will permit the increased or more efficient use of forages produced in the South, offers considerable benefits in savings on consumers' meat costs. Areas of processing research which will be undertaken include investigations on dehydrated forage products and dehydration processes, ensiling of forage grasses, and other preservation methods such as encapsulation of forage feeds. An important aspect of the work will be coordination with production research as, for example, the evaluation of new forage varieties developted by forage breeders.

Oilseeds research.—A new oilseed crop of current high interest in the South is sunflower. Utilization

research on this crop has been assigned to SEARL. In 1968 about 45,000 acres were planted to sunflowers in the South and the acreage is expected to double or triple this year. The crop has many advantages for the South. Sunflowers are a versatile crop and can be grown in rotation with a variety of crops. A farmer needs a crop for idle cotton acres. Cottonseed mills can process sunflower seeds and large capital outlays for new milling equipment would not be necessary to accommodate the new crop. However, optimum conditions for processing the seed need to be established. There are many other problems on the meal and oil which need research, as do production aspects of the crop.

SEARL will also conduct research on peanuts. Again, this assignment is consistent with location of the laboratory near the peanut producing areas of the Southeast.

Southeastern region:—One further comment may be of interest to this group since it provides the basis for our SAES Collaborators' meetings. This concerns the states included in the Southeastern region. Currently, we have defined the Southeastern Region as Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, and Puerto Rico.

The region for the Southern Utilization Research and Development Division then becomes Texas, Louisiana, Mississippi, Oklahoma, Arkansas, and Tennessee.

Although this assignment removes some States from the Southern region, we recognize that these States will retain an interest in the program of the Southern Regional Research Laboratory, and we do not want to disrupt relationships that have been built up during the years. We shall welcome, therefore, collaboration and cooperative relationships with both the Southern and Southeastern Laboratories in the areas of particular interest to States.

THE IMPACT OF THE COTTON RESEARCH COMMITTEE OF TEXAS ON THE FUTURE OF COTTON

by

C. Cox, Jr., Director
The Cotton Research Committee of Texas
Dallas, Tex.

It is indeed an honor to give the history and accomplishments of the State of Texas' role in Cotton Research, especially when given to a group as deeply interested in research as this audience.

The Cotton Research Committee (CRC) is a State of Texas government department established by the legislature in 1941, with a cotton and cottonseed research budget of $275,327 of State funds for the current fiscal year 1968-69. In addition to these State funds, another $480,575 is budgeted from other sources on co-sponsored research projects (Exhibit A). We are requesting $398,345 for 1969-70 and $429,677 for 1970-71. CRC's four members are:

Dr. John A. Guinn, Chairman-President, Texas Women's University, where we have a research unit on utilization research.

General Earl Rudder, President of Texas A&M University, where we have a complete Cotton Crushing Pilot Plant and Products Research.

Dr. Norman Hackerman, President, The University of Texas, where we do our marketing, statistical and economic research.

Dr. Grover E. Murray, President of Texas Technological College, where we have a modern Textile Pilot Plant and Fiber Laboratory.

Also, our 37-member industry Advisory Committee passes on all research projects.

The cotton crop in Texas this year was 3,457,129 bales which is over 310,000 bales more than the 1966-67 crop. Cotton in Texas still accounts for about 50 percent of the farmers' cash income from all crops. Thus, it is most important to do everything possible, as a State, to hold and expand the markets of our cotton and cottonseed products. It also should be pointed out that we produce nearly every staple length and grade of cotton including the long staple Pima and American-Egyptian varieties. Because of this wide range in length and grade of cotton it is essential that we continue to publish the fiber and spinning data results on each current crop. This stops both domestic and foreign criticism of Texas cotton, and this published data alone justifies all cotton research money appropriated by the State Legislature.

All budgets, research projects, and policy matters are reviewed by our Advisory group at regular meetings and their recommendations are presented to the Cotton Research Committee as official minutes in advance of the annual budget meetings. Our projects are the product of continuous, careful planning and close coordination which insures maximum benefits from the dollar investment in research. Also, these projects continue to pass the test of cost-benefit ratios where the industry realizes many more dollars in increased income for each dollar of public funds invested in these research programs.

We know of many specific cases where published spinning data have found new markets for Texas cottons, better prices to certain areas because of better strength or fineness test results, new products developed for shirt interlinings, and products research have stopped the rumors involved with desiccants and poisons in the cottonseed crushing industry. We have been able to take particular pride in these accomplishments as a result of work done in projects financed by CRC funds. Some of the main features are:

1. A recently published bulletin entitled "Cotton Production and Weather Data" is the culmination of a comprehensive project to relate weather and crop production conditions for Texas cotton farmers. These data, prepared by the Cotton Economic Research at the University of Texas, spread accurate 31-year weather records over every major cotton producing area in the State, indicate to the producers when the time is most favorable to plant in relation to insect infestations history, maximum yield records and favorable rainfall patterns. Anyone of the three basic factors, insect, yield, and rainfall, can save a producer up to $5 per bale on the most conservative estimates, when applied to weather data. Applied to 4 million bales, this could represent a savings of $20 million to our States cotton farmers.
2. The Cottonseed Products Laboratory has been distinguished by completing a research project for UNICEF's Childrens Fund, an organization

of the United Nations, to help in the development of cottonseed flour for protein-deficient diets in foreign countries. This has been a cooperative project between Cotton Research Committee, UNICEF, and the National Cottonseed Products Association. The Texas A&M Engineering Experiment Station's Cottonseed Products Laboratory has presented a report on this work to UNICEF which indicated that a cooker-extruder process may be the means for preparing human food containing cottonseed meats.

3. Next, through a combination of our research efforts, the "Gin Moisture Study" has stopped the criticisms of "over-drying" leveled at Texas cottons. It now appears that this extensive "crash" research program has the most significant effect of any previous projects in that the gins are now doing a better job of quality ginning and the criticisms have greatly diminished at the mill level. This was sponsored and requested by the Texas Cotton Ginners' Association and the education phase conducted by the Texas Agricultural Extension specialists.
4. "The Sheeting Study" at Texas Women's University was a research project showing the excellent wearing and laundering qualities of low Micronaire cottons and is now being applied by some of our domestic mills. Where only 2 years ago, medium-low Micronaire cottons were being restricted in purchase contracts, they are now being sought out to blend with coarse cottons. The same excellent research results were obtained at TWU showing that high cotton blends surpass the 65-percent synthetic blends on a shirt wash-n-wear utilization study.
5. Our basic research in instrument classing and evaluation is now being applied in full commercial operations. A firm in the Lubbock area, this year, processed 500,000 bales on an automatic conveyor system, classing an average of 12,000 bales per 16-hour day, checking both sides for fineness, color, prep, leaf, and then storing all these data on IBM cards for efficient merchandising to the mill or merchant.
6. The project of "Harvest-aid Chemical Residue in Cottonseed and Cottonseed Products" was given first priority by the crushing industry, especially after the "Silent Spring" publication and what happened in the "cranberry incident." It was felt that we should begin immediately on this project to have the necessary research data to stem criticism not scientifically justified. The preliminary results of this study have given us our first real insight into the *nontransferability* of these chemicals to cottonseed oil end products for human consumption and meal protein for livestock. These results have shown the Food and Drug Administration, which administers Federal Law PL 518, that the Texas Cottonseed Crushing Industry and Texas are vitally interested in facts and not "single test tube" rumors. Because of the national importance of this project, the National Institute of Health contributed $56,000 yearly to help finance this 4-year study which has now been completed.
7. The Cotton Research Committee of Texas continued to make progress in its directed avenue of effort—basic and applied research, graduate training through research projects, and diffusion of knowledge. Thus, the Advisory Committee of the Cotton Research Committee feels that the acceptance of our cotton and cottonseed research on a National level is proved by the fact that CRC's grants-in-aid contracts have increased from $21,000 in 1960 to that of $480,575 for the fiscal year 1968-69.

It should also be noted that our outside grants have doubled in the last 3 years and to hold this national respect and trust in our research program is most important. This new emergency as leaders in the field of human protein food from cottonseed, permapress finishes, statistical marketing costs, wash-n-wear utilization studies, scientific cotton fiber measurements, and a coordinating effort to tie research fabrics with fashion creators in manufacturing brings together a research effort of 60 scientists and technicians. This new level of respect by both domestic and export markets is the main justification in requesting the legislative general revenue appropriations to near or equal our outside grants. The new approach to create a broader research base that includes wool and mohair along with oilseed research shows great possibilities. It is felt that by pooling both equipment and personnel, a stronger program will evolve that serves more citizens of the State of Texas. The success of our preliminary studies concerning the spinning and weaving/knitting of wool, mohair, and cotton blends has been the real cause for the Board of Directors at Texas Tech to authorize a much-needed expansion of plant facilities at the Textile Research Center. Without this complete natural-fibers approach it would not have happened.

EXHIBIT A
COTTON RESEARCH COMMITTEE'S BUDGET SUMMARY

	Budgeted 1968-69	Biennium 1969-70	Budget Request 1970-71
Administration:			
General Revenue	$ 25,200	$ 29,000	$ 29,000
Outside Grants	1,000	1,000	1,000
Total	$ 26,200	$ 30,000	$ 30,000
Program A — T.E.E.S.			
General Revenue	$ 68,000	$ 78,000	$ 88,000
Outside Grants	57,155	72,580	76,475
Total	$125,155	$150,580	$164,475
Program B — T.A.E.S.			
General Revenue	$ 23,000	$ 45,745	$ 46,745
Outside Grants	13,000	8,000	8,000
Total	$ 36,000	$ 53,745	$ 54,745
Program C — University of Texas			
General Revenue	$ 40,669	$ 50,600	$ 50,932
Outside Grants	7,000	12,000	12,000
Total	$ 47,669	$ 62,600	$ 62,932
Program D — Texas Tech			
General Revenue	$ 74,000	$125,000	$135,000
Outside Grants	351,420	330,030	335,880
Total	$425,420	$455,030	$470,880
Program E — T.W.U.			
General Revenue	$ 44,458	$ 70,000	$ 80,000
Outside Grants	51,000	60,000	70,000
Total	$ 95,458	$130,000	$150,000
TOTAL, GENERAL REVENUE	$275,327	$398,345	$429,677
TOTAL, OUTSIDE GRANTS	480,575	483,610	503,355
GRAND TOTAL	$755,902	$881,955	$933,032

BREEDING OF NEW GLANDED VARIETIES OF COTTON

[SUMMARY]

by

J. W. Neely, Vice President and Director
Plant Breeding, Coker's Pedigreed Seed Co.
Hartsville, S. C.

Early cotton breeders sought to isolate from their stocks new varieties that represented improvements in yield, gin turn-out, staple length, boll size, picking quality, and storm-proofness.

When the boll weevil threatened the cotton industry the breeders met the challenge by developing high yielding varieties that matured early and escaped at least a part of the damage suffered by older, later maturing varieties.

When *fusarium* wilt became prevalent in many parts of the Cotton Belt and made production unprofitable, if not impossible, in large areas, the breeder developed wilt tolerant varieties that produced economic yields despite the presence of the wilt organism in the soil.

For several years cotton breeders have devoted a large part of their efforts to a study of the characteristics of a cotton variety that would be well adapted for mechanized production and to the development of varieties with as many of these characteristics as could be incorporated into a single plant.

More recently the leading cotton breeders are making full use of fiber technology in their breeding programs.

Following are the requirements for sound cotton breeding programs:

1. Understanding of the laws of inheritance.
2. Knowledge of desired characteristics.
3. Knowledge of effects of environment.
4. Breeding and testing techniques.
5. Special equipment and apparatus.
6. Adequate maintenance programs.
7. Sound business methods.

There are five steps in the typical cotton breeding program:

1. Obtaining stocks.
2. Isolating lines.
3. Testing strains.
4. Increasing seed stocks.
5. Distributing planting seed to growers.

Preliminary steps in the breeding program require 4 to 6 years. This is followed by a testing program that requires at least 8 years from the time a rather large number of isolated lines are first put into tests until a single surviving line is released for planting by farmers.

Fiber quality testing alone is a very expensive and time-consuming process. In our program each released variety has been subjected to 36 fiber tests over a period of 7 years and 17 spinning tests over a period of 5 years.

Simultaneously with testing, the breeder conducts a seed increase program designed to provide seed of a new and improved variety for release to farmers as soon as its superiority to older strains has been established.

The cotton breeder carries on a variety maintenance program simultaneously with his breeding program. Four methods may be used:

1. Roguing out off-type plants.
2. Increasing single-plant progenies.
3. Increasing massed progeny rows.
4. Massing advanced increase blocks. The most satisfactory method is the massing of advanced increase blocks that are similar to the variety to be maintained.

Outstanding varieties of cotton developed by the Federal and State experiment stations and by commercial plant breeders are results of well-planned breeding and testing programs. The future of the cotton industry depends upon the continuation of scientific plant breeding and the continued release of new and improved varieties that meet the needs of modern methods of production and manufacturing.

BREEDING OF GLANDLESS VARIETIES OF COTTON

by

R. J. Miravalle
National Cottonseed Products Association, Inc.
Memphis, Tenn.

About 1965 or 1966 the breeding of glandless cottons passed out of what can be called the "transfer" stage. Up until then most of the breeding effort was devoted to transferring, via the backcross method, the recessive gl_2 and gl_3 genes which control the glandless seed character from genetic stocks into a wide range of germplasm. Of course this change from transfer breeding to the more conventional routines of crossing and selection within a glandless background has been a gradual one.

The success achieved thus far in the breeding and development of glandless cotton is a tribute to the cooperation of public and private sectors of our society. The foresight of Henry D. Barker, former Chief of the Cotton and Cordage Fibers Research Branch, Crops Research Division, Agricultural Research Service, USDA, and Garlon A. Harper, Director of Research and Education, National Cottonseed Products Association, in immediately grasping the significance of Scott C. McMichael's discovery of glandless seed and their joining together to encourage through allocation of manpower, financial support, and otherwise the development of beltwide breeding efforts really got the glandless program moving at an early date. I want to pay particular credit to C. F. Lewis and Tom Kerr of the Cotton and Cordage Fibers Research Branch for the encouragement and support they have given public and commercial breeders alike, and especially to Dalton E. Gandy, National Cottonseed Products Association, who criss-crossed the Cotton Belt promoting the breeding of glandless cottons. Frankly, without Dalton's efforts we just wouldn't be where we are today in this program. He channeled the flow of information to those who needed it, and as you who know Dalton realize it is simply impossible to deny that enthusiasm of his. These men working with the State Agricultural Experiment Station Directors and University Agriculture Deans were instrumental in forging ahead with the glandless cotton program. But without the geneticists and breeders like Scott McMichael, Claude Rhyne, Jimmy Meyer, Angus Hyer, Josh Lee, Fred Self, Carl Mossberg, Jay Murray, Luther Bird, Levon Ray, and many others who provided the basic breeding material in the form of both seed and pollen this program would have mired down long before now. The commercial breeders have availed themselves of these sources of germplasm and have been doing and are doing a fantastic job. They have continued to breed glandless cottons while having to emphasize their breeding for better lint quality. In most instances these thave been two distinct programs when one program for total quality should clearly have been the goal. The purpose: more and better lint and seed.

The glandless variety picture is as follows:

Year of First Commercial Production	Variety	Cumulative Total
1966	'Gregg 25V"	1
1969	'Watson GL 16'	2
1970	Variety A	4
	Variety B	
1971	Variety C	
	Variety D	8
	Variety E	
	Variety F	
1972	Variety G	
to		
1975	Variety H	12
	Variety I	
	Variety J	

Until we have a glandless variety from one of the Mississippi based or Southeastern commercial breeders, the production of glandless cottons will be centered in the stripper areas of Texas and Oklahoma.

Releasing a new cotton variety is not tantamount to its being planted—far from it. Contrary to the old adage, people do not beat a path to the door of the builder of a better mouse trap. He's got to let people know about that better mouse trap before they will beat a path to his door. Any product, old or new, must be merchandised in order for it to compete for a place in the market. The same is true of cotton varieties. If a breeder doesn't have the merchandising capability to sell the products of his art and science they simply won't get planted. And, if they aren't planted the contribution these varieties would have made to improvement of the cotton crop is at best delayed until the genes from these varie-

ties can be incorporated into varieties which are planted.

The role of merchandising in crop improvement is extremely important. In years past a good cotton variety may have sold itself but not so in recent years—the competition in the seed trade is so keen that a good variety has to be merchandised!

Because the improvement wrought by glandless cotton lies in the superior quality of the seed—a byproduct whose dollar value awaits determination in the market place—the merchandising of planting seed of the first glandless varieties has understandably presented some formidable problems. We're caught on the mery-go-round of desiring produce value before we have the product. What incentive or set of incentives will induce the grower to plant a glandless cotton in preference to a glanded one? The incentive offered by the Gregg is that their 'Gregg 25V' is more tolerant to Verticillium wilt than any of the other Gregg cottons. But, because glandless seed isn't presently more tangibly remunerative to the grower than glanded seed, they didn't emphasize the glandless character in merchandising 'Gregg 25V' planting seed. On the other hand, Rogers Delinted Cottonseed Company is emphasizing glandlessness every bit as much as lint quality in their first efforts at merchandising 'Watson GL 16' planting seed. Their approach is well worth following because the rapidity with which production of glandless cotton became widespread depends in large measure on their prowess and success as a merchandiser. 1969 is definitely not the year to introduce a new variety—but is any year?

There aren't many apparent answers to merchandising glandless varieties; however, a characteristic found in both 'Gregg 25V' and 'Watson GL 16' that may be helpful is that they have higher seed grades. Oil mills buy seed on the basis of seed grade. Oil percent, ammonia percent, free-fatty acid (FFA) content, trash content, moisture content, and in some areas linters percent are the values which go into the seed grade formula. Increase in fatty acid content decreases seed grade, but low FFA does not increase seed grade. Field weathering increases FFA but in 'Gregg 25V' and 'Watson GL 16' free fatty acids are very slow to build up under conditions conducive to field weathering. We don't know whether increased seed grade and slow build up of free fatty acids are generally associated with glandless cottonseed. Breeders have been alerted to this possibility and are on the lookout for this in their materials. Research on how general this slow buildup of FFA in glandless cottonseed might be is being considered at present.

Results of utilization research conducted at this laboratory and at State experiment stations, especially the prospect for making food products from glandless cottonseed, have stimulated cotton breeders to really put out for glandless cotton. Nothing has so motivated the breeder to work on glandless cotton as has this food angle. It has been the single most important factor to our getting glandless cottons so quickly. Really it has been quick—slightly less than 10 years from the time of discovery to the release of the first glandless cotton variety. In time I look to see the results of utilization research becoming the important factor in merchandising glandless planting seed to the grower.

You want to know, really everybody wants to know, how soon it will be before glandless cottons are in production in appreciable quantity. How does one go about getting a cotton with special features bred and into production in the shortest possible time? Or, put another way, how does one move from the genetics of a potentially valuable trait to the actual realization of the worth of that trait in the crop? In general how does one maximize the returns from a genetic improvement in the cotton crop?

With the exception of specific areas in the Western States, the cotton crop is almost exclusively made up of varieties bred by commercial breeders. Public-agency cotton improvement programs contribute largely to variety improvement through exchange of germplasm. Variety improvement precedes crop improvement. How then can this cooperation between public-agency and commercial breeders be enhanced so as to shorten the time from discovery to improvement of the cotton crop? I think we can profit from what has taken place in the glandless endeavor, and at this time I'd like to share with you some of my experiences and observations relevant to this issue.

An ethic-of-sorts apparently exists among cotton breeders, there are exceptions to be sure, but the majority of cotton breeders will not make a varietal release of another breeder's germplasm or selection he had made from another breeder's germplasm, even when the originating breeder gives his permission for and encourages such a varietal release, unless exclusive rights to the germplasm are granted, but will:

observe another breeder's germplasm for its potential value as a parent in crosses, and

utilize another breeder's germplasm or selec-

tions he has made out of another breeder's germplasm in crosses.

The breeding populations resulting from such crosses are considered by the breeder who made the cross as his own material and hence feels quite free to release and merchandise varieties he may develop from such breeding populations. In the glandless endeavor breeders made use of the early releases of seed and pollen to make crosses. This was quite natural then but not now when the releases from public agencies are in many instances already of varietal status. This ethic-of-sorts acts to delay the public-agency-bred cotton varieties from making a contribution to the improvement of the cotton crop until their genes find their way into commercial breeders' varieties. Thus, direct contribution by public-agency varieties to the improvement of the cotton crop is practically non-existent outside the West. This is such a waste.

There is no question that public agencies need to stay in cotton breeding and equally no doubt that they will not get into seed merchandising or that a commercial breeder will merchandise such varieties for public agencies without an exclusive franchise. What then? Since breeders use released germplasm, or selections therefrom, in crosses to develop segregating populations, that is, germplasm pools, the public agency breeders could make such germplasm pools directly available. In this way crossing would be eliminated and commercial breeders could proceed immediately with selection in such germplasm pools. Ideally, these pools should be relatively unselected, but they should be of proved value. By proved value, I mean that selected lines from the pool should be tested to evaluate and demonstrate the worth of the pool to produce improved cottons. Under the present organization of breeding programs, only the worth of selected lines themselves is evaluated, with the better one or ones being released as a single line or multiline variety. The unselected germplasm pool is never maintained—at least I know of no case where it is.

If, in addition to the present exchange of selected proved germplasm, an exchange of unselected but proved germplasm pools is made available I believe improvement of the cotton crop will progress more rapidly than it has. Certainly we will have to move faster with the incorporation of such traits as Frego bract, nectariless, okra leaf, and glabrous leaf into the cotton crop than we have with glandless seed. The procedure I have outlined is one way to sustain an accelerated improvement of the cotton crop. Commercial breeders need and would use unselected proved germplasma pools which are homozygous for glandlessness, Frego bract, nectariless, okra leaf, and glabrous leaf or for combinations of as many of these traits as they can obtain. It is likely that any two breeders who might request seed from the same germplasm pool would select and develop varieties from it that are any more similar than varieties developed under the present system. Public agency breeders would need to make only a slight alteration in their present operations; namely, they would have to preserve the germplasm pool. Incidentally, the development, maintenance, and evaluation of unselected proved germplasm pools offers a better training ground for plant breeders than we have at present. Geneticists may suffer as a result. Instructional considerations are not so incidental from the University's standpoint or, for that matter, to the future of cotton improvement either.

I have purposely given you the broad concepts of this approach, each breeder would have to work out the details most suitable to his own operation. However, if anyone would care to pursue this matter further, I will be delighted to meet with you anytime during our stay here.

Before I leave the microphone I want to tell you how appreciative the cotton industry, especially the cottonseed products segment, is for the fine work and splendid cooperation of this lab, the several State experiment stations and universities and the many collaborators in bringing the glandless work forward. Glandless cotton production is indeed within our grasp. But, as I have indicated, we aren't over the hump yet! Your continued counsel, support, and encouragement are very much needed as we now embark on the task of establishing this NEW VERSION OF AN OLD CROP. There is still much to be done and we are counting on your understanding and your help in meeting the demands of tomorrow.

RESEARCH IN AGRICULTURAL ECONOMICS AT THE DELTA BRANCH EXPERIMENT STATION

[SUMMARY]

by

W. K. Porter, Jr.
Delta Branch Experiment Station
Stoneville, Miss.

Research in agricultural economics at the Delta Branch Experiment Station has been principally concerned with reducing production costs for cotton and cotton farms since 1964. This work has been in two areas. The first has dealt with determining costs, performance rates, and labor requirements associated with four-, six-, and eight-row equipment. The second area has been concerned with evaluating systems of cotton production which will reduce production costs without affecting yields.

The first of these studies, comparing four-, six-, and eight-row equipment, was begun in 1964 and completed in 1969. Approximately 60 farmers in the Mississippi Delta cooperated in this study by keeping records of every task performed in one cotton and one soybean field on each farm. These data were supported by 306 questionnaires obtained from farmers on their 1966 and 1967 crops.

Results of this study indicate that direct or out-of-pocket costs can be reduced from $3.50 to $5.00 per acre if cotton production of six-row equipment is substituted for four-row equipment. A reduction of $4.50 per acre in fixed costs would result from this substitution. This study also indicated farms with 600 acres or more of cropland which use six-row equipment investment in farm machinery was 25 to 35 percent less than farms using four-row equipment. Substitution of six-row for four-row equipment reduced the permanent labor force on these farms up to 30 percent. Farms using six-row equipment worked 52 acres more cropland per worker and 63 acres more cropland per tractor on the average than farms using four-row equipment.

The second study concerned with cotton production systems was begun in 1965. This study indicates that seedbed preparation work can be done in several ways without affecting yield. Planting flat or on beds did not affect yields. Planting in last season's stubble with no seedbed preparation also gave as good yields as more traditional methods of seedbed preparation. Seedbed preparation costs have ranged from $6.36 per acre to $8.79 per acre (direct costs).

Weed control systems including preplant and pre-emergence herbicides, postemergence herbicides, mechanical cultivations, flaming and hoeing were evaluated. Costs for the various systems ranged from $18.47 to $23.09 in the same year. No differences in yield have been observed between any systems. No economic justification can be found for the broadcasting of any herbicide.

Total direct production costs have ranged from $85 to $146 per acre with no significant difference in yields.

INNOVATIONS IN THE GINNING OF COTTON

[SUMMARY]

by

V. P. Moore
U.S. Cotton Ginning Research Laboratory
Leland, Miss.

Through the ginning research program recommendations have been developed for the cleaning, drying, and ginning of machine-picked and machine-stripped cottons. These recommendations have become pretty much the standard of the industry.

For machine-picked cotton the following sequence has been found to be optimum; Feed control, tower dryer, six to seven cylinder cleaner stick and green leaf machine, a second tower dryer, a second six to seven cylinder cleaner, extractor feeder, gin stand, and two lint cleaners.

The dryers should be operated at temperatures that will provide lint in the 7 to 7½ percent moisture content range. The gin stands should be operated within the manufacturer's recommended capacity.

The foregoing amount of machinery is a compromise between grade and staple for the producer and spinning quality for the mill.

During the past few years there has been an increasing shortage of gin labor. Because of this labor shortage, research has been initiated to find ways and means of reducing the number of man-hours required for ginning a bale of cotton. In this connection, a new unloading system for cotton has been developed which will reduce power 95 percent and labor 75 percent. This system consists of some means for mechanically dumping a trailer of cotton into an open pit which contains a feed mechanism for automatically metering seed cotton to the ginning system.

Initial research on this system has been completed and it has been turned over to the ginning industry. One of these units has been built and operated during the past season. The unit is operated by one man at a capacity in excess of 30 bales per hour.

The packaging of cotton at the gin is a second area which shows promise for the reduction of power and labor requirements. After conferences with textile machinery design engineers, research has been undertaken to design a completely new packaging system. Although this research is only in the preliminary stage, calculations show that it may be possible to reduce connected horsepower and labor requirements by as much as 75 percent within the next few years.

CPI RESEARCH—1968/1969

by

G. S. Buck, Jr.
National Cotton Council of America
Memphis, Tenn.

I have been asked to give you a report on the research programs of Cotton Producers Institute. I welcome this opportunity because so many of you are engaged in Federal, State, or private industry research on cotton, and quite a few of you have direct responsibilities for carrying out a part of the CPI research program.

I am not going to make any attempt to describe all of the different lines of research in the CPI program. We have published a summary of the program and copies are available if you don't already have one. It seems more important at this time to convey some of the philosophy behind the CPI research effort and to discuss some of the more important objectives which the CPI Trustees hope to attain with the help of this new producer-supported program.

First, a word about the dimensions of the program would be appropriate. This past year, 1968, was the first year of CPI operation under the Cotton Research & Promotion Act. In the period from 1962 through 1967, CPI research reached a total of 1 million dollars in only 1 year. The 1958 CPI effort, in contrast, was equivalent to 2.7 million dollars for cotton research.

For the current year the Trustees of CPI have allocated 3.6 million for research, and this, together with staff and other support from the Cotton Council, brings the producer-and-industry contribution to more than 4 million dollars in 1969. This is roughly equivalent to the cotton research input by the 14 cotton producing States, but less than one-fourth of total federal funds for cotton research, which will approximate 18 million dollars this year.

These comparisons make it perfectly clear that the USDA and the States still carry the major share of responsibility for cotton research. It is of real concern to the industry, therefore, that the Federal and State programs have not expanded significantly within recent years. Federal support for cotton research, for example, is up about 11-1/2 percent in 1969 from the 1967 level. However, the cost of research, still rising at 6 percent each year, cancels out any real gain from those increased funds. A major effort will, therefore, be made this year to persuade the new Administration and the Congress that substantial increases should be provided for cotton research. Particularly for the vital cost-cutting research and extension programs, I know that there are many individuals in this meeting today who will be working actively to support this effort.

Make no mistake about it, it is not only urgent, but absolutely essential that a bigger and more effective research and educational program be directed toward reducing the costs of producing cotton. Let me take a minute or two to review the present situation of the U.S. cotton industry, which is at this time in very serious straits—fundamentally as a result of production costs which are too high.

During the past 7 or 8 years, we have had repeated demonstration of what happens to cotton's markets when its price gets too high—first when the new Administration in 1961 increased the price of cotton, and again within the past 2 years when curtailed production and bad weather brought about shortages —or the fear of shortages—and high prices. The consequences have been increasing substitution of rayon, polyester, and other synthetic fibers for cotton, increases in foreign cotton production, substantial declines in exports of U.S. cotton, continued curtailment in acreage allotments, and even higher costs and losses to cotton farmers and other segments of the cotton industry. The market losses which cotton experienced were further aggravated by the durable-press development, about which I will have more to say later.

A competitive price for cotton is considered to be somewhere in the neighborhood of 23¢ per pound. But we know, from recent USDA studies, that the average cost of producing a pound of cotton is somewhere around 28¢ to 30¢. This difference has been made by direct payments to farmers from the Federal treasury. These payments are only partly effective, however, when shortages push the price of

cotton too high. Furthermore, many producers question the wisdom of continuing dependence on heavy Federal subsidies.

This situation has reduced the morale of cotton producers to a new low. And their pessimism is justified, unless substantial reductions can be made in the cost of producing cotton, and that soon. There is no other answer to the basic problem, and that is the challenge for research.

We think cotton production costs can be cut. We think they can be cut substantially. Of course, we don't have enough research today to bring costs down the full amount that is needed; but, we think we can use our present programs—the Federal-State-CPI-programs—to demonstrate some very significant savings in many parts of the Belt. And, because few things would be more encouraging to producers or more revitalizing to the industry than a demonstration that we can, in fact, overcome some of our major cost problems, we need to do this quickly.

The CPI research program is pointed right toward some of the most promising cost cutting opportunities. More and more in 1969 emphasis will be shifted toward developments which farmers and the industry can use *now* in their own operations. It will be obvious to all of you that it has taken a lot of Federal, State, and industry research input to make it feasible for us to pursue such a course today.

INSECT CONTROL

We think that insect control, and particularly better control of the boll weevil, offers one of our prime opportunities to reduce costs in cotton production. The pink bollworm and the bollworm also offer potentials for cost saving, although perhaps not quite as immediate as the boll weevil. CPI research is focused on all three insects. We are convinced that important benefits can be realized soon.

In the case of the boll weevil, CPI is supporting additional research on the diapause method at the University of Arkansas, and the Council will provide assistance this year to states carrying out demonstration diapause programs. As a method of cleaning up the weevils successfully over winter after diapause program, CPI continues to support research on chemosterilants in cooperation with USDA, and also to push research on systemics, such as TEMIK. Additional demonstrations of a combination of diapause and spring cleanup will be carried out in 1969 and the spring of 1970.

We feel strongly that the time has come to start an eradication program on the boll weevil. We know that there are still many uncertainties about such a program. We know that further research is needed. Nevertheless, we think a start can be made. If some mistakes are made, they won't be any more costly than waiting additional years to refine every last technique. Specifically, we are proposing expanded, State-wide diapause programs, to be followed in the spring with an effective systemic on every acre planted to cotton. Later, when adequate means of sterlizing weevils are perfected, clean-up releases can be added to the spring program where needed.

It will take time to work out the logistics of a weevil eradication program. New State laws and new Federal regulations may be required. Many decisions will have to be made—where to start, how much territory can be covered at a time, how much buffer zone will be needed, what chemicals and other materials will have to be on hand, how the program will be monitored, and others. But let's get started on this *NOW*, recognizing that research is still continuing and the methods we use may be improved before we get done.

Even if we don't achieve eradication at the start, we know that we can reduce boll weevil control costs with the diapause program alone. So we really have nothing to lose, and a great deal to gain. Very frankly, I don't think we can afford *not* to go ahead with this program.

The worms will be more difficult.

In the case of the pink bollworm, CPI is supporting research on cultural control methods, on systemic insecticides, and on the use of biological agents such as the Trichogramma. We are also watching carefully the work with sterilized insect releases of U.S. Department of Agriculture and California State. Just as soon as a useful combination of methods can be put together, we feel that the pink bollworm should be attacked with the same vigor as that to be directed against the boll weevil.

We don't see any easy way to eliminate the third of these insects, the bollworm, but we certainly ought to be able to do a better job of controlling it. Obviously, if we can eradicate the weevil, problems of the bollworm will be reduced. But other methods of control are also promising. CPI is supporting research on resistant plants, pathogens, and parasites, and on systemic chemicals effective against lepidopterous larvae. In all likelihood it will take a combination of such methods to give effective and economical control of the bollworm.

WEEDS

The control of weeds stands out as an important example of what research can do to cut production costs. About 85 percent of cotton acres are now treated with chemical herbicides. Some problems remain, of course, with certain weeds, and in certain soils and production situations. In 1969, CPI will continue research on Johnsongrass nutsedge, problems of herbicide use in sandy soils, herbicide effectiveness in the High Plains, and herbicide usage in the irrigated Far West.

DISEASES

CPI research on cotton diseases is concentrated on verticillium wilt, seedling diseases, and boll rots. At this time we do not foresee any quick or easy solution to any of the three. We are learning a great deal more about verticillium wilt, however, through the five research studies on that disease which CPI is now supporting. The progress with systemic fungicides looks especially encouraging. Just as soon as we see any method which promises to be commercially feasible, I can assure you that the CPI Trustees will call for an all-out effort to make it available commercially to farmers.

YIELD AND QUALITY

Some of the most important advances in cotton production efficiency may come from fundamental physiological and biochemical research. But this is long-range research. We can't expect the results—the payoff—next year, or the year after. However, if we are planning to stay in the cotton business over the long run, we cannot afford to overlook opportunities to improve both yield and quality through this type of research. It is encouraging to note that both the States and the Department of Agriculture are increasing their basic research. CPI is cooperating in studies at Texas A&M, in California, Georgia, and North Carolina.

MECHANIZATION

In mechanization the opportunities are clearly of a type that can provide the farmer with early benefits. CPI research on new ways to apply chemicals is a good example. The control of partical size in sprays, the reduction of drift, the use of ULV materials, and more uniform incorporation of herbicides in soil all offer possibilities of increasing chemical efficiency. Other research which seems to us to hold a real potential includes precision planting methods, and systematized programming of operations and equipment use. CPI is supporting research in these areas.

GINNING, HANDLING, MARKETING

Now let's look at one more place where there is a big potential for cutting costs. This is in the area between the farm and the mill. A CPI study at Texas Tech shows, for example, that in some cases half of the mill cost of cotton goes for operations performed after the cotton leaves the farm. I mean ginning, packaging, hauling, transportation, compression, storage, marketing, shipment, etc. In general, these costs have tended to rise and to cancel out some of the gains we have been able to make in production efficiency.

I think it is becoming generally recognized that we can no longer afford the present level of costs in ginning, handling, and marketing cotton. We can no longer afford to do things in the traditional way when a better way is available. We can no longer afford to use big labor crews where automation will do the job. We can no longer afford to package a bale poorly, to use covering material that gives less than full protection, to tear the package apart through repeated sampling, to recompress it to different sizes and densities, or to evaluate the quality of the fiber by methods which are both obsolete and inadequate.

The job for research is to demonstrate what can be done to improve efficiency in all of these operations. That is the objective of CPI studies at Texas Tech, Georgia Tech, and Research Triangle Institute in North Carolina. Once we know what can be done, I think the demands of producers, together with the competitive pressures, within the industry will force the adoption of more efficient methods in just a few years.

I cannot overemphasize the absolute necessity of pursuing every one of these avenues to lower cost and greater efficiency. There is no way that the American cotton industry can survive without becoming competitive in price. Fortunately, there is ample opportunity to reduce costs both on and off the farm. It is a big job, and it will take a big and determined effort in research, and in the extension of research, to get the job done.

NEW PRODUCTS

You all know, of course, that cutting costs and becoming competitive in price will not by itself assure the U.S. cotton industry of a future. Cotton will also have to compete in quality with synthetic fiber products, and CPI is helping here also.

The importance of competing in quality can be seen in what has happened to many of cotton's markets during the past 3 years because of a lack of fully satisfactory durable-press properties. Cotton's share of the trouser market dropped from 73 percent[1] in 1964 to 51 percent[1] in 1968. Its share of the dress-shirt market dropped from 86 percent in 1964 to 45 percent last year. Just last year durable-press began to be a factor in the big sheet and pillowcase market, which is equivalent to over 900,000 bales a year. As a result, blends were estimated to have about 22 percent of the market in 1968 and are projected to have 40 percent in 1969. Just 2 years ago, 100-percent cotton held 91 percent of this big market.

Cotton simply must have satisfactory durable-press. No single quality improvement has ever been so important to this industry. That is why nearly half of the entire CPI research effort in 1969 will be directed toward improving permanent press finishes for cotton products. More than a score of different research programs will be carried out this year in over a dozen institutions in this country and abroad. The most highly trained and competent scientists in this field have been enlisted in this vital effort. The Trustees of CPI have indicated their readiness to devote even more of their funds to these programs, if necessary.

Although the CPI investment in durable press research was very modest up until last year, and was even in 1968 considerably under the size of the program to be carried out this year, I can report to you that we have made excellent progress. Several large industries have signed license agreements to commercialize new CPI durable-press processes. Other agreements are being negotiated.

It will, of course, take some time for these firms to gear up for full-scale production, and it will not be until 1970 that the new cotton durable-press products begin to reach the market in substantial volume. But, from then on we can look forward with confidence to finding increasing quantities of all-cotton durable-press in more and more markets, and more and more products.

This has been a tough problem—one of the most difficult that the cotton industry has ever faced. Many research organizations—public and private—have contributed to the progress that has been made. Even now I don't want to characterize the accomplishments as a breakthrough, because they have for the most part come about slowly, step by step. Furthermore, there is ample evidence that even more significant progress is yet to be made. Developments still in the early laboratory stages look very promising indeed.

We can say with assurance, however, that cotton has met the challenge of durable-press. Cotton will be fully competitive in durable-press trousers, durable-press sheets, durable-press shirts, and other products where this quality of easy maintenance and freedom from ironing is so important to consumers.

But we won't be able to rest there. We won't be able to slacken our research effort. There will be new requirements to meet, like soil release, fire resistance, whatever new quality our competitors introduce next year or the year after. If cotton wants to stay in business, it will have to match its competitors in these qualities. So we have a big job in research across the board. We have to meet the urgent challenge of reducing cotton production and handling costs so that we can compete. Then we have to add new qualities and new properties to match our competition. We have demonstrated, I think, that research can do the job. But it will take all the resources we can obtain, and all the determination we can muster to do the whole job and keep it buttoned down. The fact that you are here today indicates your interest, and in most cases your direct participation in these programs. I want to commend you for what you have already done and to urge you to even greater efforts to rebuild and revitalize the American cotton industry.

[1] Includes pocketing and trim.

FABRIC STRUCTURE AND ITS RELATION TO DURABLE PRESS PROPERTIES

by

G. J. Kyame, G. F. Ruppenicker, Jr., and H. W. Little
Southern Utilization Research and Development Division
New Orleans, La.
(Presented by G. J. Kyame)

The role of fabric structure in the wear performance of all-cotton, durable-press fabrics was sought in earlier research[1] [2] conducted on summer-weight suiting fabrics woven from yarns made from Pima S-2 variety of cotton. Two hundred and eighty-eight experimental fabric structures were evaluated. Half of these were made from plied yarns and half from equivalent singles yarns. Two levels of yarn size, two levels of yarn twist, four weave types, and three levels each of warp and filling thread counts were investigated. Evaluation of the fabrics by repeated laundering revealed that their performance depended chiefly on fabric weave, fabric thread count, and the size and kind of yarn used. The limited number of parameter level explored, however, precluded a clear understanding of the influence of these parameters on fabric performance. This paper presents the results of an expanded investigation wherein the number of levels of some parameters were increased to more clearly elucidate the results.

MATERIALS AND METHODS

Fifty-four mediumweight experimental fabrics were woven. These encompassed combinations of two weaves, two yarn sizes, three warp thread counts, and from three to six filling thread counts, the number being limited by fabric weaveability on the one hand, and aesthetic acceptability on the other. Figure 1 shows organization chart of the fabrics woven. Yarns for the fabrics were spun from a two-bale blend of 1-1/8 in. Middling, American Upland cotton of 4.6 micronaire reading and 76 percent maturity. The warp yarns were 10/1 (60 tex) and 15/1 (40 tex) spun to 4.10 T.M. and sized with a 12-percent add-on of conventional starch sizing. The filling yarns were 10/1 and 15/1, spun to 3.60 T.M. Thirty-three of the fabrics were three-seconds regular twills and 21 were plain-woven.

Fifty-two additional experimental fabrics were prepared and evaluated for: (a) the effect of filling yarn size, (b) the effect of filling yarn twist, (c) the effect of variations in the plain and twill weaves, and (d) a study of sateen fabrics. A report on these supplementary studies is presented in a separate paper.[3]

Finishing operations for all the fabrics included desizing, scouring, bleaching, and drying on a tenter frame under minimum tension settings. The bleached fabrics were given a conventional durable-press finish by padding on approximately 6 percent by weight of DMDHEU (dimethylol dihydroxethyleneurea). The treated fabrics were dried on a tenter frame at 150° F. to a moisture content of about 9 percent.

One-yard samples of each of the treated fabrics were pressed flat in a steam-heated, hot-head, legger press, and cured for 8 minutes in a circulating hot air oven set for 320° F. The cured samples were given a single washing to remove unreacted resin and catalyst, then tumble-dried. Physical properties were then determined by standard ASTM test procedures.[4]

To determine fabric performance under repeated laundering, four 12-inch long by 9-1/2-inch wide, cuffed, trouser legs were prepared from each of the sensitized experimental fabrics. These were creased, pressed, cured, and given a preliminary washing and tumble-drying. Wash-wear appearance and crease appearance were then rated substantially in accordance with AATCC test procedures.[5] Test standards were AATCC three-dimensional plastic replicas for rating wash-wear appearance, and AATCC Photographic Standards for rating crease appearance; both were used with overhead lighting.

---

[1] Kyame, G. J., Harper, R. J., Lofton, J. T., and Ruppenicker, G. F. Jr. Improved Durable Press Through Fabric Structure and Polymer Treatment. Amer. Dyestuff Rptr. 57: P662-P667. 1968.

[2] Kyame, G. J., Lofton, J. F., and Ruppenicker, G. F. Jr. The Effect of Fabric Structure on Durable Press Performance. *In* Proc. Seventh Cotton Utilization Research Conference, U.S. Dept. Agr., Agr. Res. Serv. ARS 72-63. pp. 54-59. 1967. Textile Bull. 94(6): 37-39. 1968.

[3] Ruppenicker, G. F. Jr., Kyame, G. J., and Little H. W. The Influence of Yarn Parameters and Weaves on The Durable-Press Properties of Cotton Fabrics. *In* Proc. Eighth Cotton Utilization Research Conference. U.S. Dept. Agr., Agr. Res. Serv. ARS 72-70, pp. 111-122. 1969.

[4] American Society for Testing Materials. ASTM D1295-53T, D1682-59T, D1424-59, D1175-55T. 1966.

[5] American Association for Textile Chemists and Colorists. AATCC Tentative Methods 88A-1964T and 88C-1964T, Tech. Manual 41: B99-103, B104-105. 1965.

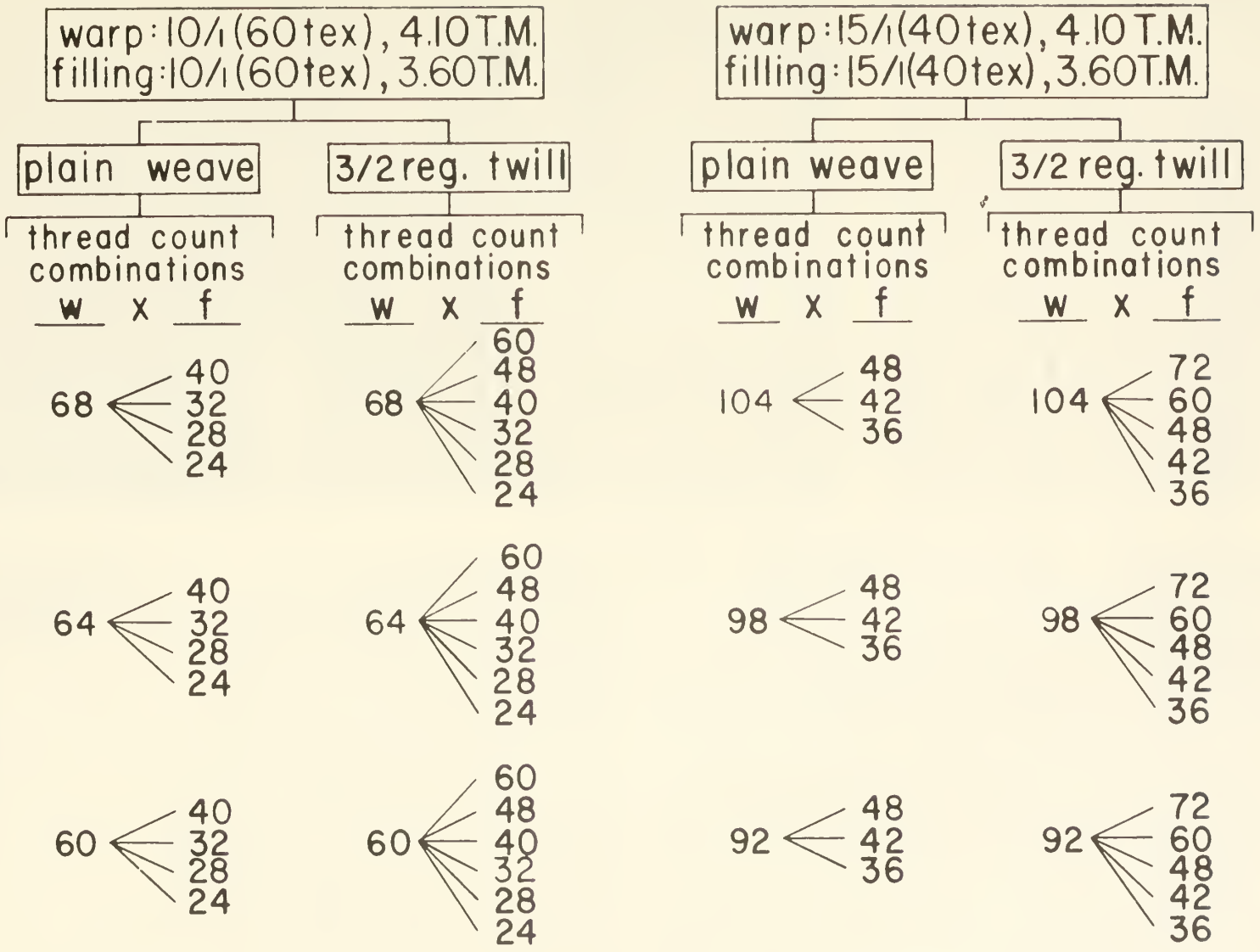


Figure 1.—Fabric organization chart.

All washing was done in 4-pound batches. Each batch was washed with 25 grams of Tide detergent in a Kenmore Model 600 washer operating through a normal cycle, that is, normal tub and agitator speeds, water temperature at about 105° F, 10-minute wash period, four rinses as follows: (1) spin-spray, (2) regular rinse, (3) deep rinse, and (4) spin spray, each of 2 minutes duration, and a 4-minute spin-drying period. Tumble-drying was carried out in an electrically heated, Kenmore Model 600 drier at a temperature of about 140° and a drying time of 45 minutes.

Having determined the initial appearance ratings after the first laundering, the test trouser cuffs were given 29 additional launderings with inspections for damage after each cycle for the first five cycles. Subsequent inspections were made at cycles of 7th, 10th, 12th, 15th and so forth. Fabric damage was classified under three categories: (1) Cycles to first failure (the breakage of a single thread), (2) cycles to first major damage (two or more crossing threads broken, or four or more parallel threads broken at the same site), and (3) the total number of holes after 30 launderings. This paper reports the findings under the first category, cycles to first failure.

RESULTS AND DISCUSSION

The susceptibility of mediumweight fabrics to early damage was clearly evident in the comparatively few launderings needed to cause fabric breakdown. This was particularly true of the plainweave fabrics. Five of nine plain-wovens made from 15/1 yarn, and four of twelve made from 10/1 yarns failed between the fifth and seventh laundering cycles. This casts some doubt on the usefulness of these data for differentiating between the plain-woven fabrics, a fact that is given due consideration in the discussions that follow.

Statistical simple linear correlations were calculated to show relationships between fabric performance in repeated laundering and several of the fabrics' physical properties. These are given in table 1. In discussing the tabulated results, the correlation coefficients are categorized as follows:

Less than 0.60	poor
0.60-0.79	fair
0.80-0.85	good
0.86-0.95	very good
0.96-1.00	excellent

Correlations for the plain-weave fabrics are poor in most instances, no doubt the result of the fabrics' lack of durability to repeated laundering. Poor correlations are shown for all properties of the fabrics made from 15/1 yarns. The fabrics made from the 10/1 yarns, however, show a number of meaningful correlations. Fair correlations are indicated for warp tearing strength, filling breaking strength, bursting strength, flat abrasion, filling flex abrasion, filling stiffness, and resin add-on. The best correlation for these fabrics is the good −0.80 given for warp stiffness.

The twill weaves fare better. More than half the parameters tested were significantly correlated with laundering cycles to first hole formation. The degree of correlation ranged from fair (0.62) for the filling tearing strength of the fabrics made from 15/1 yarns, to very good (0.89) for both the flat abrasion of the 15/1 yarn fabrics and the warp stiffness of the 10/1 yarn fabrics.

In an overall analysis wherein the data for all 54 fabrics were combined, only two parameters correlated significantly with laundering durability. These were filling tearing strength (good, 0.81) and resin add-on (fair, 0.67). The indicated dependence of laundering durability on resin add-on is somewhat disturbing in that it implies a possible contribution of resin add-on to the variations in performance of the different fabric structures. However, the poor correlation with crease recovery angle, which is closely associated with resin add-on, minimizes this concern.

Numerous variance analyses of the data were made for all properties measured. Only those analyses that reveal relationships with fabric performance measured in terms of cycles to first failure will be discussed.

Fabric weave type plays a major role in determining a fabric's durability to laundering. This is demonstrated by the F-ratios given in table 2. Considering the 10/1 and 15/1 fabrics separately, the effect of weave is seen to be significant at the 99-percent probability level for both sets of fabrics. Filling thread count is also a major contributor to durability being significant at the 99-percent level for the 10/1 fabrics, and at the 95-percent level for the 15/1 fabrics. Interaction between filling thread count and weave type is significant at the 95-percent level for both sets of fabrics. Warp thread count, warp thread count-weave type interaction, and warp thread count-filling thread count interaction do not have a significant influence on durability-based F-ratios. In the overall analysis, the effects of weave

and filling thread count on laundering durability are significant at the 99-percent level, and filling thread count-weave interaction is significant at the 95-percent level. No other significant effects are noted.

The greater number of levels of filling thread count permitted a more detailed analysis of the effect of filling thread count on fabric performance. Preliminary plots of the data indicated a geometric relationship between the variables, so nonlinear regression models were used. Figure 2 shows the least squares curve computed from the data for the 10/1 twill weave fabrics. Experimental data points are also plotted to show the scatter of the data about the calculated curve. The equation representing the curve is:

$$\log y = 3.76 - 1.56 \log x$$

where

y = average cycles to first failure
x = filling thread count

The closeness of fit of the calculated curve to the experimental findings is evidenced by the relatively high correlation coefficient r = -0.93.

Superimposed on the figure are linear regression lines computed from associated data for fabric stiffness and crease recovery angle. Linear regressions were assumed in making these calculations. The influence of fabric stiffness on fabric performance is clearly evident.

Table 1.—Simple correlation coefficients of fabric properties with average cycles of first failure

Fabric property	Correlation coefficients of—				
	Plain Weave		Twill Weave		Combined data
	10/1	15/1	10/1	15/1	
Tearing strength:					
Warp	0.73	-0.25	0.13	0.31	0.48
Filling	0.44	0.37	0.76	0.62	0.81
Breaking strength:					
Warp	0.22	-0.38	-0.30	-0.08	0.24
Filling	-0.76	-0.06	-0.85	-0.84	-0.49
Elongation-at-break:					
Warp	-0.55	-0.15	0.01	-0.78	-0.53
Filling	-0.28	0.31	-0.67	-0.87	0.20
Bursting strength	-0.64	0.12	-0.39	-0.81	-0.36
Flat abrasion	-0.65	-0.38	-0.77	-0.89	-0.37
Flex abrasion:					
Warp	-0.30	-0.45	-0.71	-0.74	-0.57
Filling	-0.63	-0.26	-0.76	-0.79	-0.56
Stiffness:					
Warp	-0.80	-0.31	-0.89	-0.85	-0.44
Filling	-0.70	-0.33	-0.85	-0.88	-0.45
Resin add-on	0.60	-0.25	0.72	0.03	0.67
Crease recovery angle:					
Conditioned	0.17	-0.46	0.14	0.02	-0.13
Wet	0.39	-0.36	0.58	0.57	0.41

The importance of yarn size in determining fabrice durability is demonstrated by the F-ratios in table 3. The effects of yarn number and of filling thread count are significant at the 99-percent level for the twill weave fabrics and in the overall analysis but are not significant for the plain-weave fabrics. The effect of warp thread count is significant at the 95-percent level for the twill fabrics only. None of the interactions was significant.

The significance of thread count in determining fabric durability is illustrated by the F-ratios in table 4. The filling thread count effect is significant at the 99-percent level in the 10/1 and 15/1 twill fabrics and in the overall analysis, and at the 95-percent level in the 10/1 plain-weave fabrics. Warp thread count was of significance in only the 15/1 twill fabrics (95-percent level). The general lack of statistically significant effects of warp thread count in this table and in tables 2 and 3 is believed due to using only three levels of warp thread count in the experiment.

Table 2.—Analysis of variance F-ratios—effect of weave on average cycles of first failure

Source of variation		10/1	15/1	Combined data
Weave	(W)	[1]336.89	[1]121.66	[1]388.21
Filling thread count	(C_f)	[1]20.03	[2]14.16	[1]25.44
C_f x W		[2]7.51	[2]10.71	[2]11.39
Warp thread count	(C_w)	4.29	3.53	3.28
C_w x W		1.94	0.07	0.23
C_w x C_f		1.01	1.22	0.37

[1]Significant at the 99-percent probability level.
[2]Significant at the 95-percent probability level.

Table 3.—Analysis of variance F-ratios—effect of yarn number on average cycles to first failure

Source of variation		Plain weave	Twill weave	Combined data
Yarn number	(Y)	0.62	[1]104.85	[1]67.48
Filling thread count	(C_f)	1.91	[1]46.35	[1]25.44
C_f x Y		0.83	1.61	0.69
Warp thread count	(C_w)	1.70	[2]5.74	3.28
C_w x Y		0.10	2.20	0.91
C_w x C_f		0.16	0.49	0.37

[1]Significant at the 99-percent probability level.
[2]Significant at the 95-percent probability level.

Table 4.—Analysis of variance F-ratios—effect of fabric thread count on average cycles to first failure

Source of variation	Plain weave		Twill weave		Combined data
	10/1	15/1	10/1	15/1	
Filling thread count	[1]9.58	0.13	[2]40.47	[2]48.12	[2]25.44
Warp thread count	1.97	1.31	7.08	[1]5.11	3.28

[1]Significant at the 95-percent probability level.
[2]Significant at the 99-percent probability level.

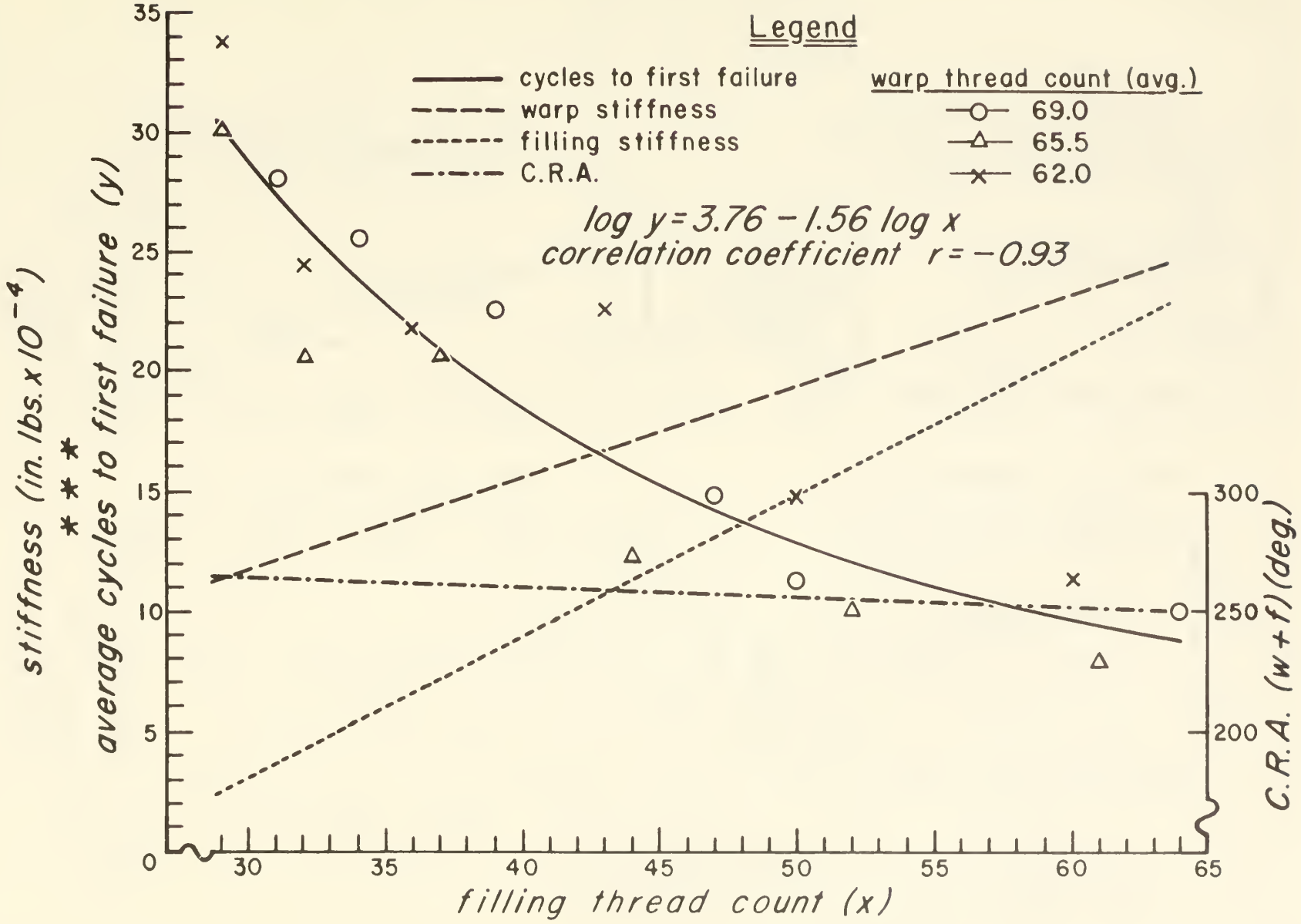


Figure 2.—Performance of the twills woven from 10/1 yarn.

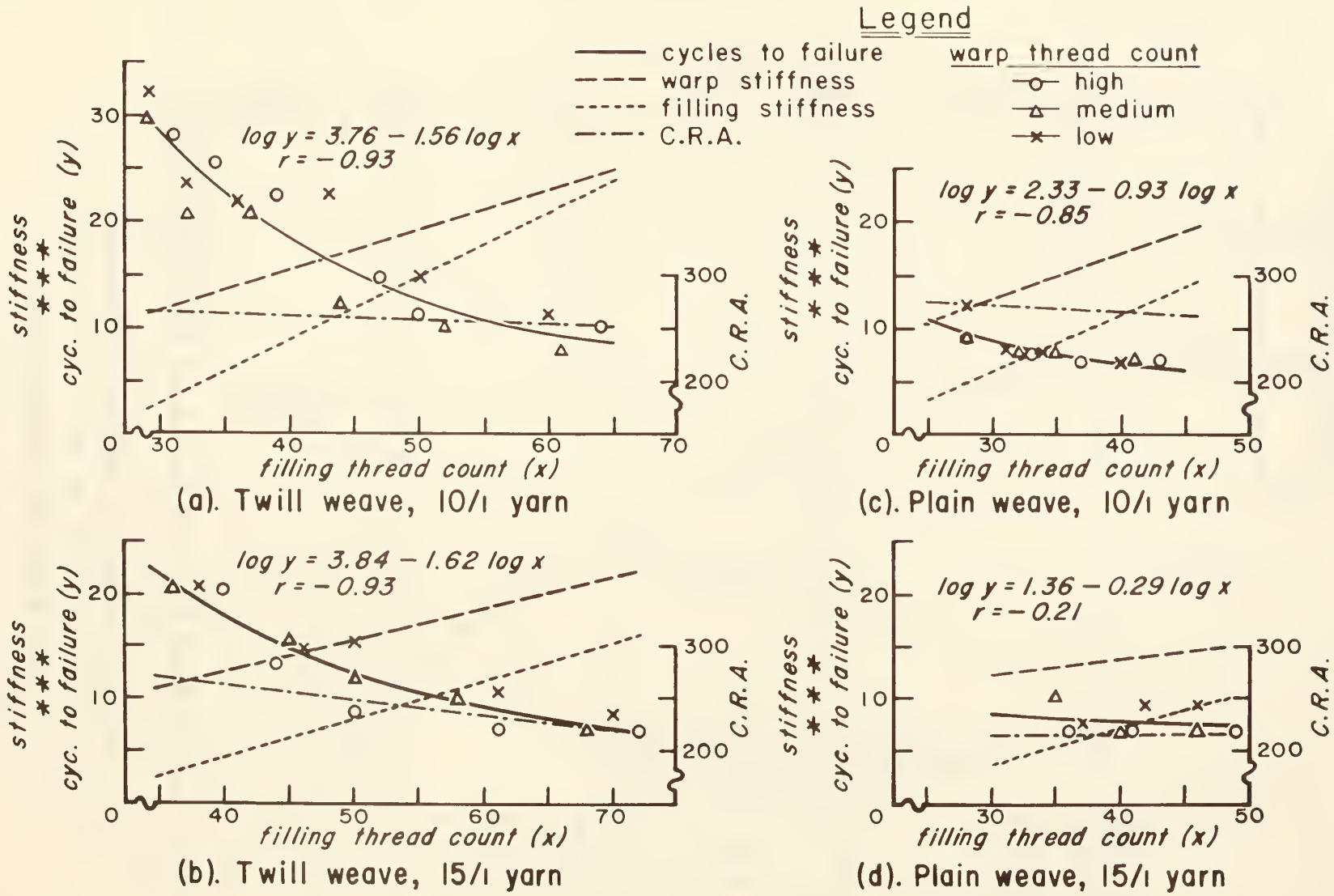


Figure 3.—Performance of the experimental fabrics.

Increasing stiffness, whether in the warp or in the filling direction, produces a corresponding decrease in the number of laundering cycles required to cause fabric failure. A slight negative slope in the CRA line indicates increasing CRA with decreasing filling thread count. Normally, this would mean fewer cycles to failure for the fabrics with the lower thread count, but the tendency in this direction is far overshadowed by the predominant effect of fabric structure.

Figure 3 is a composite of figure 2 (fig. 3a), and three similar plots of the data for the 15/1 twills (fig. 3b), the 10/1 plain weaves (fig. 3c), and the 15/1 plain weaves (fig. 3d). The results in each case are similar, only the magnitudes differ. It is interesting to note the close similarity in the equations calculated for the twill fabrics:

(1) $\log y = 3.76 - 1.56 \log x$ (for the 10/1 twills)

(2) $\log y = 3.84 - 1.62 \log x$ (for the 15/1 twills).

Rounding off the numerical quantities to the first decimal makes the equations identical. More research is needed to determine if this is meaningful.

Despite the poor performance of the plain weave fabrics, the effect of filling thread count is still clearly evident in figures 3c and 3d in that it again overrides the normal effect of CRA. Stiffness and crease recovery angle show relationships similar to those observed in the twill fabrics. In figure 3d, the comparative flatness and near horizontality of the performance curve is clearly the result of the breakdown of more than half the experimental fabrics by the seventh laundering cycle. The limited usefulness of this set of data is evidenced by the extremely poor correlation coefficient, $r = -0.21$.

SEQUEL

The foregoing points up the enormity of the problem of relating the durable-press performance of a fabric and the structural parameters of the fabrics. The findings thus far allow only generalizations. It is clear that some weaves perform better than others; singles yarns outperform equivalent plied yarns in fabrics of the same kind and weight; and coarse yarns outperform fine yarns in equivalent fabric constructions. Much more research must be undertaken to determine the prerequisites for predicting a fabric's durable-press performance on the basis of its structural parameters. The Southern Utilization Research and Development Division is continuing basic research along these lines.

ACKNOWLEDGMENTS

The authors deeply appreciate the participation of many coworkers in the Division's Cotton Mechanical Laboratory, Cotton Finishes Laboratory, and the Textile Testing Investigations in the preparation, finishing, and testing of the many experimental fabrics. The financial support of the Cotton Producers Institute is gratefully acknowledged.

THE INFLUENCE OF YARN PARAMETERS AND WEAVE VARIANTS ON THE DURABLE PRESS PROPERTIES OF FABRICS

by

G. F. Ruppenicker, Jr., G. J. Kyame, and H. W. Little
Southern Utilization Research and Development Division
New Orleans, La.
(Presented by G. F. Ruppenicker, Jr.)

ABSTRACT

The effects of weave, yarn size, and yarn twist on the durable-press properties of medium weight, all-cotton suiting fabrics are reported. Fabrics woven from several twill, plain, and sateen weaves were evaluated. Relationships between the home laundry performance of these fabrics and laboratory abrasion tests are discussed.

INTRODUCTION

The market for durable-press fabrics has experienced spectacular growth over the past few years. As a part of the Southern Regional Research Laboratory's overall research program to develop improved all-cotton durable-press products, investigations have been conducted to determine the effect of various yarn and fabric structure parameters on the properties of durable-press cotton fabrics.

Previous research determined the home laundry performance and other properties of lightweight durable-press suiting fabrics made from both single and plied cotton yarns.[1] [2] Generally, fabrics woven from singles yarns showed much better resistance to laundry wear than did those woven from plied yarns. Twill weaves provided the best resistance to wear, followed in order by sateens and plain weave fabrics. In most cases, an increase in thread count adversely affected wear because of laundering. Another study of heavier suiting fabrics woven from singles yarns produced similar results.[3] The heavier weight fabrics wore much faster than the lighter weight fabrics.

This paper reports the effects of weave, yarn size, and yarn twist on properties of mediumweight, all-cotton, durable-press, suiting fabrics. Fabrics woven from several twill weaves, variations of the plain weave, and some sateen constructions were evaluated. Relationships between the home laundry performance of these fabrics and laboratory flex abrasion tests are discussed.

MATERIALS AND METHODS

Yarns for the study were spun from a two-bale blend of 1-1/8 inch, middling American Upland cotton with a Micronaire reading of 4.6. Fabrics ranging in weight from 7.50 to 9.00 oz./sq.yd. were woven from 10/1 and 15/1 warp yarns and from 7.5/1 to 15/1 filling yarns.

The fabrics were scoured, bleached, and treated with the following formulation containing an imidazolidone-type resin, Permafresh 183:

18 percent Permafresh 183
4 percent OE Velvetol (softener)
3.2 percent Catalyst X-4
Balance water

The resin solution was applied on a padder to a wet pick-up of approximately 65 percent and dried on a tenter at 150° F. to a moisture content of from 8 to 9 percent.

For determining the treated fabrics' durability to laundering, the sensitized fabrics were made into cuffed trouser legs measuring approximately 9-1/2 inches wide by 12 inches long. These were fabricated with the warp yarns running lengthwise. The cuffs were pressed on a steam-heated, automatic press on cotton setting and then cured in a hot air, circulating oven for 8 minutes at 320° F. Four cuffs were made from each fabric. Additional sets of cuffs were made from the twills and sateens with the backs of

[1] Kyame, G. J., Lofton, J. T., and Ruppenicker, G. F. Jr., The Effect of Fabric Structure on Durable Press Performance. *In* Proc. Seventh Cotton Utilization Research Conference. U.S. Dept. Agr., Agr. Res. Serv. ARS 72-63, pp. 54-59. 1967. Textile Bull. 94(6): 37-39. 1968.

[2] Kyame, G. J., Harper, R. J., Lofton, J. T., and Ruppenicker, G. F., Jr. Improved Durable Press Through Fabric Structure and Polymer Treatment. Amer. Dyestuff Rptr. 57: P662-P667. 1968.

[3] Kyame, G. J., Ruppenicker, G. F., Jr., and Little H. W. The Relation of Fabric Structure to the Durable-Press Properties of Mediumweight Cotton Fabrics. *In* Proc. Eighth Cotton Utilization Research Conference. U.S. Dept. Agr., Agr. Res. Serv. ARS 72-70, pp. 100-110. 1969.

the fabrics exposed to the outside. All were washed and tumble dried a total of 30 times in standard home laundry equipment with a normal wash cycle, in accordance with AATCC procedure.[4]

The cuffs were checked after every second and fifth wash-dry cycle and the number of cycles to failure recorded. A single broken thread, either warp or filling, was considered a minor failure. A break in both warp and filling, or a break in four or more warp or filling yarns at the same site constituted a major failure. In some instances both minor and major failures occurred on the same wash cycle. Holes developing in the hemmed, upper edge of the test specimens were not counted. Crease damage was assessed separately.

After the first laundering and at the end of the evaluation, the cuffs were rated for wash-wear appearance and sharpness of creases. Rating procedures followed substantially those recommended by the AATCC.[4] The test standards were AATCC plastic replicas for rating wash-wear appearance, and AATCC photographic standards for rating crease appearance.

Abrasion resistance and other physical properties were measured on samples of the fabrics pressed flat, cured, and laundered once to remove unreacted resin and catalyst. The fabrics were tested in accordance with ASTM procedures.[5]

RESULTS AND DISCUSSIONS

Generally, all the fabrics had excellent durable-press properties. The fabric treatment resulted in an average resin add-on of about 5.7 percent. Wash-wear and crease appearance ratings averaged 4.0 or better after both one and 30 launderings. The average crease recovery angle (conditioned, warp + filling) was approximately 272°.

The resin-treated fabrics exhibited substantial decreases in strength and abrasion resistance. Table 1 shows the properties of a 9-oz. warp face sateen fabric and after resin treatment. Breaking strength decreased 50 percent warpwise and over 60 percent fillingwise. Tear strength losses were somewhat less—approximately 13 percent warpwise but over 37 percent fillingwise. There were decreases in flex abrasion resistance of up to 80 percent compared with untreated fabric.

Table 1.—Properties of a sateen fabric before and after resin treatment

Property	Untreated[1]	Treated[2]	Percent decrease
Breaking Strength (lb.):			
Warp	146	72	50.6
Filling	150	57	62.0
Tear Strength (gr.):			
Warp	2,867	2,500	12.8
Filling	3,300	2,067	37.4
Flex Abrasion (cycles):			
Warp	665	155	76.6
Filling	1,110	220	80.1

[1]Scoured and dyed fabric.
[2]18 percent Permafresh 183

Plain Weave and Related Fabrics.—Plain weave fabrics are used extensively as suiting and trouser materials. Previous work has shown that all-cotton, durable-press, plain weave fabrics exhibit very poor wearing qualities in repeated home laundry tests. This is believed to be because of the high degree of yarn interlacings that restrict yarn movement and thereby make the fabric more susceptible to edge wear. In the present study, several plain weave derivatives including the oxford, 2/2 warp rib, and 2/2 basket were evaluated. Some fabrics woven with a six-harness mock leno weave were also included. Figure 1 shows the laundry performance of these fabrics compared with plain weave fabrics. The results are averages for 8 oz./sq.yd. fabrics woven from both 10/1 and 15/1 yarns. The average number of cycles to first failure and to first major failure are shown for each weave type. There was very good correlation between the two levels of measurement. Most of the initial failures were warp yarns. All the derivative weaves performed better than the plain weave, with the basket weave fabrics having the best laundry durability. There was very little difference in wear between the oxford and plain weave fabrics. An examination of the cuffs after 30 launderings revealed that those woven from the plain weave fabrics also had extensive crease damage.

Figure 2 shows the flex abrasion resistance of plain weave fabrics. Flex abrasion was measured with a Stoll Universal Wear Tester. In this test, the fabrics are subjected to unidirectional rubbing and folding action as opposed to wear on a folded edge

[4]American Association for Textile Chemists and Colorists. AATCC Tentative Methods 88A-1964T and 88C-1964T, Tech. Manual 42: B102-106, B107-108. 1966.
[5]American Society for Testing Materials. ASTM D1295-53T, D1682-59T, D1424-59, D1175-55T. 1966.

determined by laundry tests on the cuffed trouser leg specimens. The results for flex abrasion resistance were generally opposite to those for launder performance. The plain and oxford weave fabrics had the best flex abrasion resistance, both warpwise and fillingwise.

Twill weave fabrics.—Figure 3 shows the home laundry cycles to major failure for some twill weave fabrics comparable in weight and construction to the plain weave type fabrics already discussed. Cuffs for laundering were made with both the face and back sides exposed. Generally, the durability to home laundering increased as the length of the yarn floats increased. The 2/2 twill wore much better than the 2/1 twill. Very little difference in wear existed between the face and back sides of the fabrics. There was no apparent crease damage for any of the twill fabrics after 30 home laundry cycles.

The flex abrasion resistance of twill fabrics is shown in figure 4. The results were inconclusive. Fillingwise, abrasion resistance decreased as the length of the yarn floats increased. The 2/2 twills behaved approximately the same on both sides. There was a much greater difference between warpwise and fillingwise abrasion resistance on the back side than on the face side of the fabrics. In most cases, the highest values were obtained when the abrasive action was perpendicular to that of the predominantly exposed yarns.

Sateen fabrics.—Figure 5 shows the effect of home laundering wear on cuffs made from three sateen fabrics, each weighing approximately 9 oz./sq.yd. One fabric was woven with 10/1 yarns, another with 15/1 yarns, and the third with 15/1 warp yarns and 10/1 filling yarns. These fabrics were laundered and tested with both the face and back sides exposed. The fabric woven with 10/1 warp and filling yarns withstood about twice as many laundry cycles as the others before showing major failure. Examination after 30 launderings showed some crease damage in the fabric woven from 15/1 yarns. There were no real differences in wear between the face and back sides of the fabrics. However, with the face exposed, initial failures were warp yarns, whereas with the back exposed, initial failures were filling yarns.

The fabric woven with 15/1 yarns in both the warp and filling had the best flex abrasion resistance. As with the twill fabrics, the highest values were obtained when the abrasive action was in the opposite direction to that of the exposed floats. There were no significant differences in flex abrasion resistance between the face and back sides of the fabrics.

Effect of yarn number on wear.—The effect of yarn number on home laundry performance is shown in figure 6. Plain and 3/2 twill weave fabrics weighing approximately 7.5 oz./sq.yd. were woven from 10/1 and 15/1 warp yarns and 7.5/1, 10/1, 12.5/1, and 15/1 filling yarns. Another series of 8 oz./sq.yd. fabrics was woven from the same yarns. Fabric weights in each series were held constant by adjusting the thread count to compensate for changes in yarn size. The results shown are the combined averages for the 7.5 and 8.0 oz./sq.yd. fabrics. Laundry performance improved with an increase in filling yarn size for both the plain and twill weaves. In contrast to the sateen fabrics shown in figure 5, warp yarn number had no significant effect on wear for this group of fabrics. However, it is possible that a greater range in warp yarn number may have shown some differences. The 3/2 twills withstood from two to three times more laundry wear than the plain weave fabrics. As already noted, the plain weave fabrics had extensive crease damage after 30 home laundry cycles.

Warpwise the fillingwise, flex abrasion resistance decreased as the filling yarn size was increased. Fabrics woven from both the 10/1 and 15/1 warp yarns showed the same trend. The plain weave fabrics were considerably better in this property than the twill fabrics.

Effect of yarn twist on wear.—The laundry performance of 8 oz./sq.yd. fabrics woven from filling yarns spun with three different twist multipliers ranging from 3.10 to 4.10 is shown in figure 7. All warp yarns were spun with a 4.10 twist multiplier. The results shown are averages for fabrics woven from both 10/1 and 15/1 warp and filling yarns. Filling yarn twist had no significant effect on laundry wear for either the plain or twill weave fabrics. These results agree with previous findings that neither warp nor filling yarn twist has a significant effect on laundry wear[1 2]. The twills wore much better than the plain weave fabrics. There was very little difference between cycles of first failure and cycles of first major failure for the plain weave fabrics, many of which failed both ways on the same laundry cycle.

Filling yarn twist had no significant effect on flex abrasion resistance. The plain weave fabrics were much better in this property than were the twills. Higher values were obtained when the fabrics were

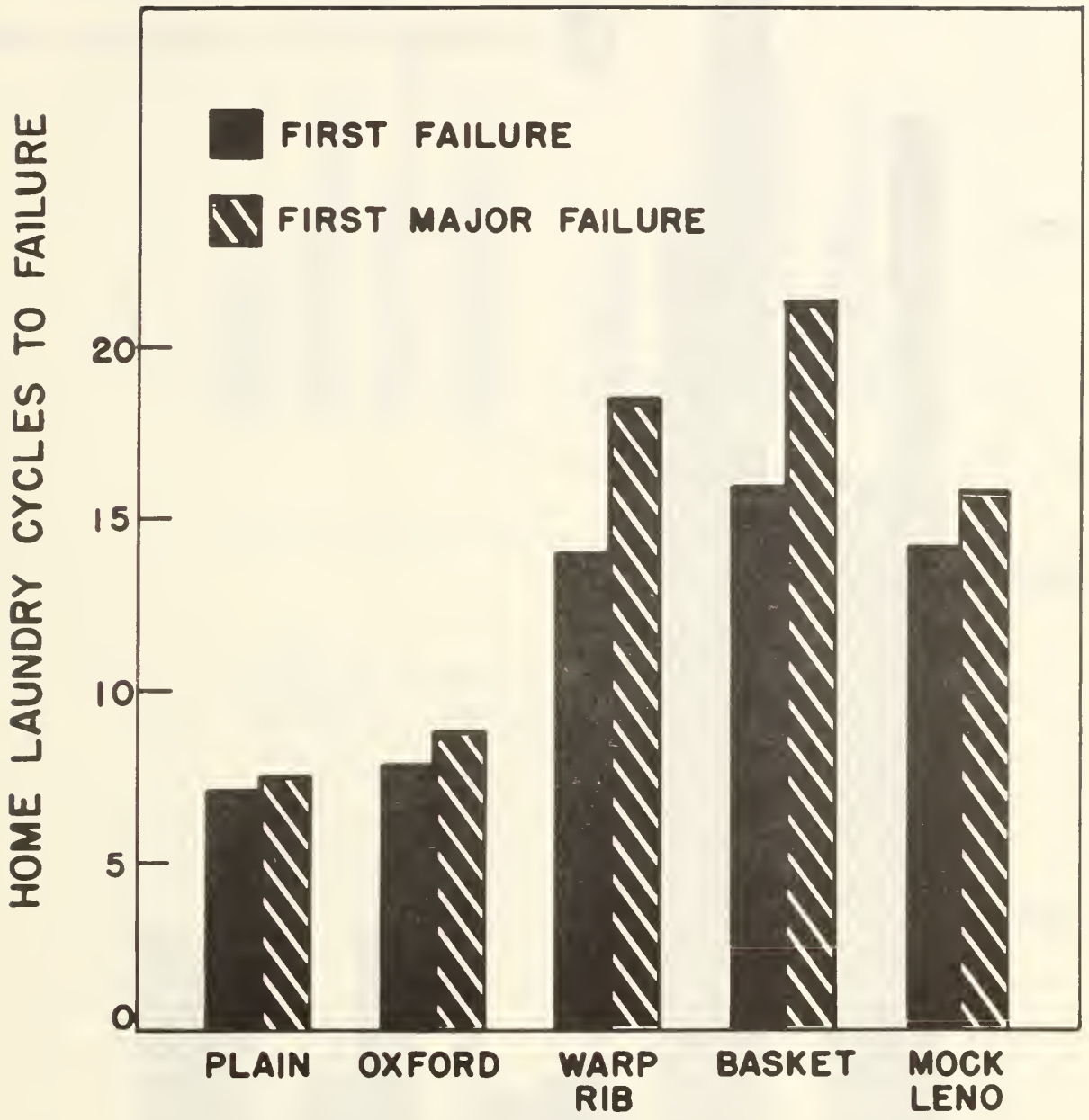


Figure 1.—Home laundry performance of plain weave type fabrics.

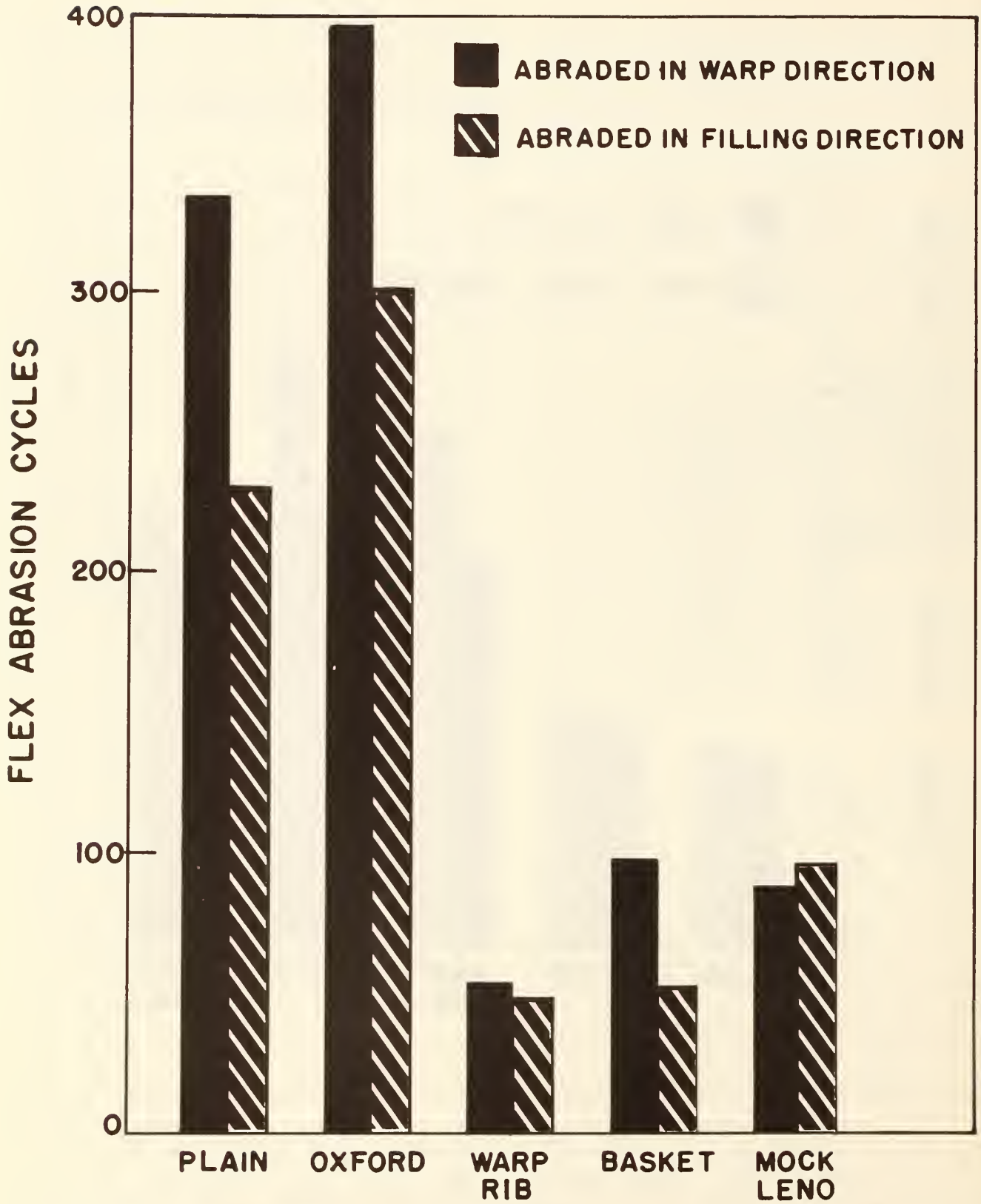


Figure 2.—Flex abrasion resistance of plain weave type fabrics.

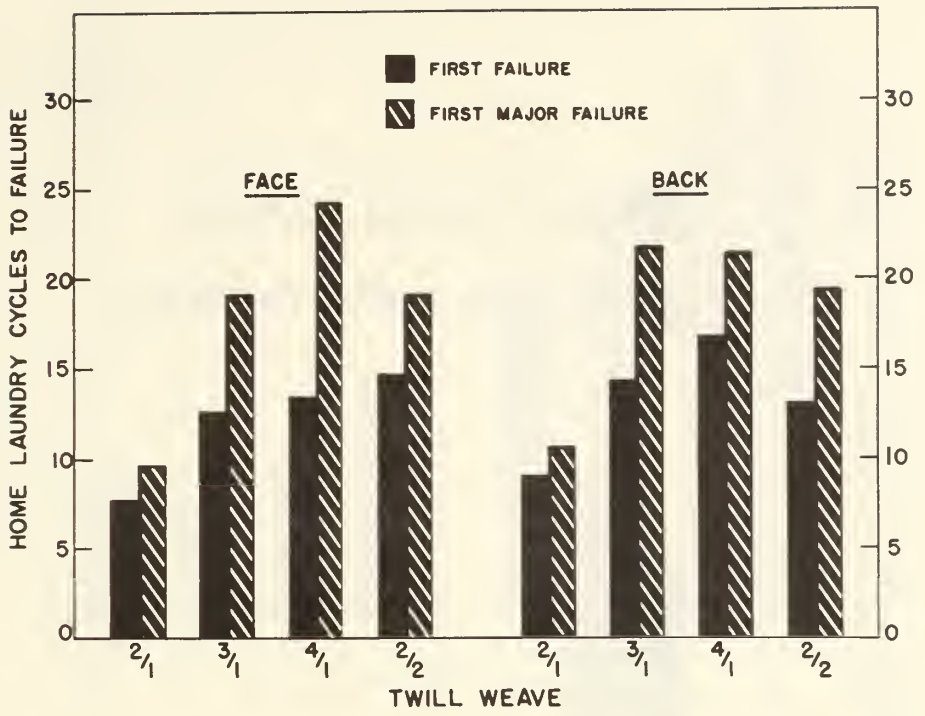


Figure 3.—Home laundry performance of twill weave fabrics.

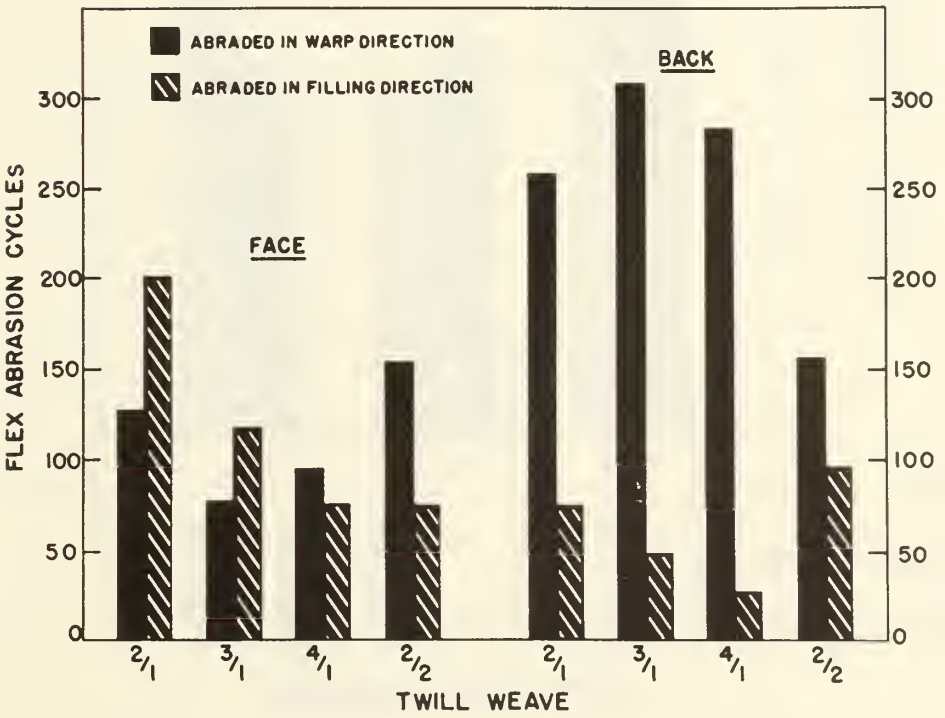


Figure 4.—Flex abrasion resistance of twill weave fabrics.

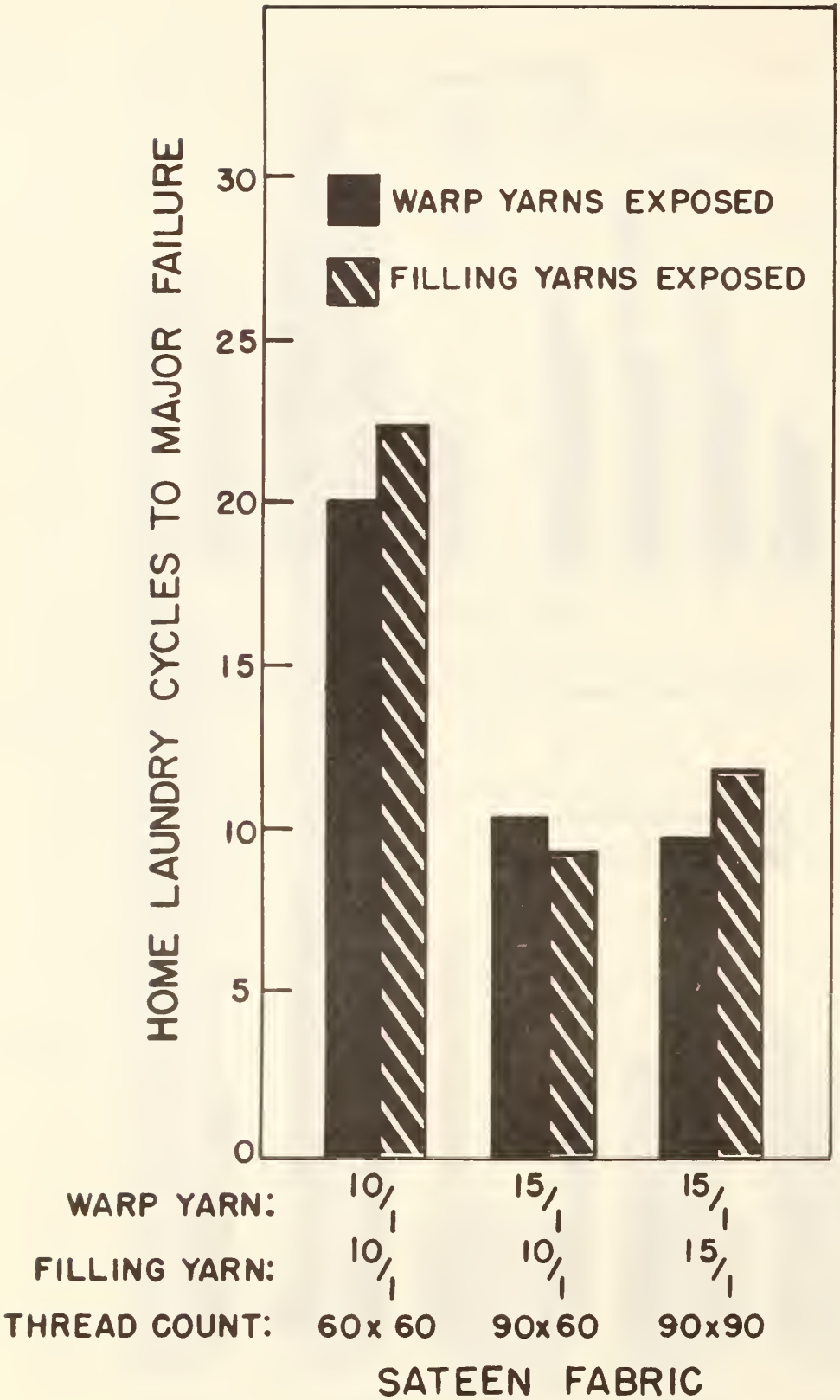


Figure 5.—Home laundry performance of sateen.

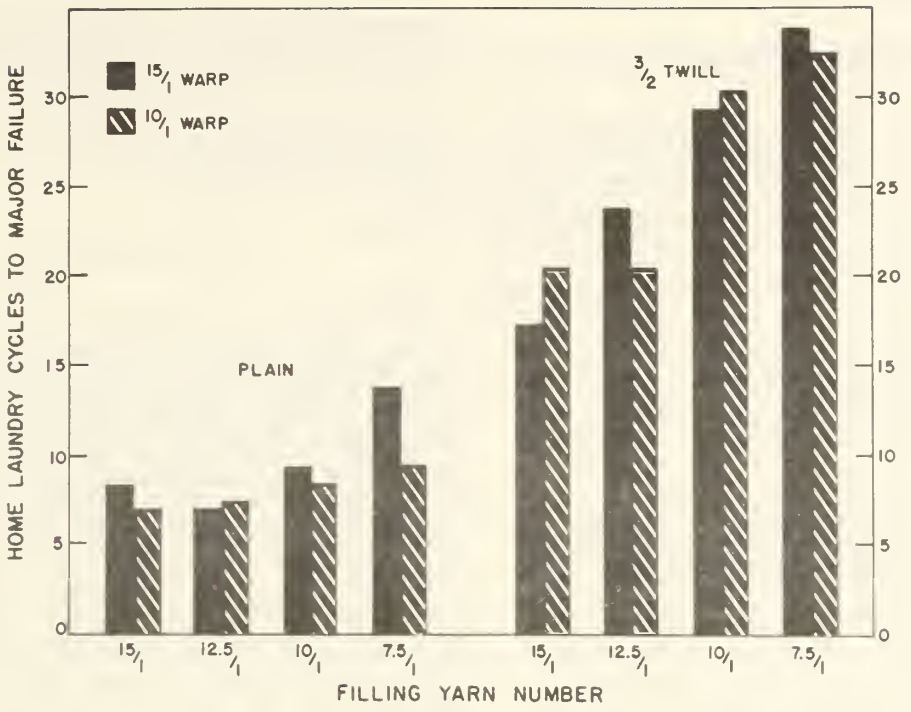


Figure 6.—Home laundry performance of fabrics woven from different yarn numbers.

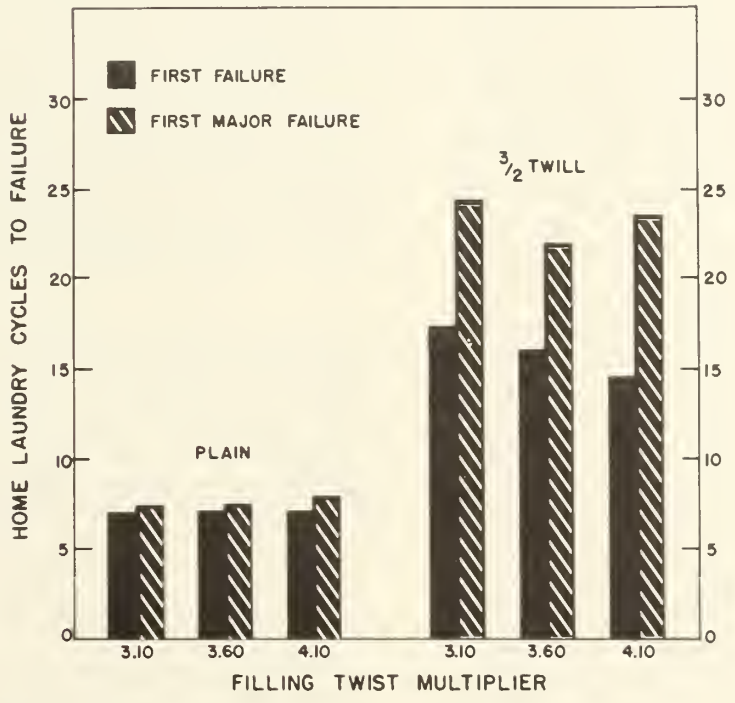


Figure 7.—Home laundry performance of fabrics woven from filling yarns having different twist multipliers.

abraded in the warpwise rather than the fillingwise direction.

SUMMARY AND CONCLUSIONS

Differences in the laundering wear of the durable-press cotton fabrics investigated appear to be caused primarily by the effect of yarn mobility within the fabric structure. Plain weave fabrics exhibited poor laundry wear compared with the more flexible baskets, ribs, twills, and sateens. Fabrics woven from coarse filling yarns wore better than those of comparable weight woven from finer yarns. Yarn twist had no significant effect on fabric performance. Neither were there any real differences in wear between the face and back sides of the twill and sateen fabrics.

The results of flex abrasion resistance were, in most cases, opposite to those for laundering wear. The plain weave type fabrics had the best flex abrasion resistance, but the poorest laundry wear. Fabrics woven from finer yarns produced better flex results than those woven from coarse yarns. Filling yarn twist had no significant effect on flex abrasion resistance. Nor were there any real differences between the face and back sides of the twill and sateen fabrics in this property.

ACKNOWLEDGMENTS

The authors express their sincere appreciation to coworkers in the Division's Cotton Mechanical Laboratory, Cotton Finishes Laboratory, and the Textile Testing Investigations for their contributions in the preparation, finishing, and testing of the fabrics. They gratefully acknowledge the financial support of this study by the Cotton Producers Institute, and the cooperation of the National Cotton Council of America.

DURABLE PRESS COTTON FABRICS WOVEN FROM POLYMER-SIZED YARNS

by
J. T. Lofton, R. J. Harper, H. W. Little, and E. J. Blanchard
Southern Utilization Research and Development Division
New Orleans, La.
(Presented by J. T. Lofton)

INTRODUCTION

Scientists at the Southern Regional Research Laboratory and other laboratories have shown that treating cotton fabrics with durable polymers extends the wear life and improves the smooth-drying appearance of all-cotton durable-press fabrics. Research on polymer-treated fabrics has been reported by Abrams and Sherwood (1); Sherwood (6); Harper, Blanchard, and Reid (5); Wolfgang (7); and Blanchard, Harper, Gautreaux, and Reid (4). Researchers at the Southern Regional Research Laboratory are still exploring the use of polymers in finishes for woven cotton fabrics to upgrade certain properties for specific end uses.

This paper is a progress report of research conducted to develop improved all-cotton fabrics for use in durable-press garments through the application of polymers to cotton yarns before weaving and to determine the effects of fabric structure and finishing processes on the physical properties and wearability of these fabrics. Experiments in the initial phase were designed to find the two best performing polymers to be used for the subsequent phases of this project. The bases for the selection of these two polymers were: (1) Their contribution to the desirable properties needed in cotton durable-press fabrics, and (2) their effectiveness as a size in the weaving process.

Exploratory work showed that fabrics woven from polymer-sized yarns and treated with resins by postcure techniques had a desirable hand without the boardiness frequently associated with polymer-treated fabrics. Cuffs fabricated from these experimental fabrics sustained 50 home-type launderings without damage and retained a warp plus filling wrinkle recovery angle of 300°.

MATERIALS AND METHODS

The polyurethane latices used in this investigation were listed as E-406 and E-503 produced by Wyandotte Chemical Corporation.

The polyacrylates used were E-269 and E-358 produced by Rohm and Haas.

The other polymer used was a commercial butadiene styrene copolymer with a trade name of Pliolite Number 2498 produced by Goodyear Tire and Rubber Co.

Crosslinking agent Permafresh 183 and 183K, along with Catalyst X-4 (Sun Chemical Co.), and softeners used in this work were commercial products. Permafresh 183K is a low temperature curing resin. Another crosslinking agent used, dimethylol methoxyethyl carbamate (DMMXEC), was UCET Carbamate Finish 4G marketed by Union Carbide. The polyvinyl alcohol (PVA) was DuPont's Elvanol 50-42 and the carboxymethylcellulose (CMC) was Hercules' CMC Warp Size.

Yarns used in this work were spun from a two-bale blend of Acala 4-42 cotton processed in a conventional manner. All fabrics were woven from one warp count, 40 tex (15/1 cotton count), and one filling count, 50 tex (12/1 cotton count). In all cases the woven fabrics were 74 x 54 thread count, 2/2 regular twills weighing approximately 7 oz./sq. yd. Warp yarns and some filling yarns were sized on a laboratory continuous range which was modified to operate as a hot air slasher. Filling yarns were also sized in skein form.

Test procedures.—To determine the physical properties of the treated fabrics, 1-yard samples of each were pressed in a steam-heated automatic press on cotton setting and cured for 8 minutes in a circulating oven set for 320° F. The cured samples were washed to remove unreacted resin and catalyst and then tumble-dried. After the samples were dried, ASTM test procedures *(3)* were followed in determining their physical properties.

To determine performance in the washing machine, four 12-inch long by 9-½-inch wide cuffed legs were made from each of the experimental fabrics. These were pressed, cured, and then subjected to repeated laundering. The cuffs were laundered in 4-pound batches in a Kenmore Model 600 washing machine.

The washed cuffs were tumble-dried for 45 minutes in an electrically heated Kenmore Model 600

drier at a temperature of about 140° F. The cuffs were examined after each five cycles of laundering. Any rupture at one location was classified as a hole and recorded. Cuffs were graded for wash-wear and crease ratings after the first and thirtieth laundry cycles. The wash-wear ratings were determined by use of overhead lighting with the AATCC Three Dimensional plastic replicas while crease ratings were determined with AATCC Photographic Standards (2).

RESULTS AND DISCUSSIONS

Durable-press fabrics woven from polymer-sized yarns were compared with control fabrics treated in a conventional manner and with control fabrics with combination treatments equivalent to the finishes given the yarn-treated fabrics.

Fabrics Woven from Polymer-Treated Warp and Filling Yarns.—

Thirty-two experimental fabrics were woven from warp and filling yarns treated with four different polymers. These thirty-two fabrics consisted of two replicates of the 16 possible combinations of the four polymer-treated yarns using a polymer-treated yarn in both the warp and filling direction. The design and identification of the experiment is shown in table 1.

Table 1.—Design and identification of polymer-treated yarn experiment

Filling	Warp			
	Polyacrylate 358 A	Butadiene styrene copolymer B	Polyurethane E-406 C	Polyacrylate 269 D
Polyacrylate 358-A	AA	BA	CA	DA
Butadiene-styrene Copolymer-B	AB	BB	CB	DB
Polyurethane 406-C	AC	BC	CC	DC
Polyacrylate 269-D	AD	BD	CD	DD

The same concentration of a given polymer was used for both the warp and filling yarn treatments. The warp yarns were slashed under tension while the filling yarns were treated in skeins, dried, and rewound for quilling. The fabrics woven from these treated yarns were scoured and bleached without appreciable stripping of the polymer. Each yarn-treated fabric was given a pad-dry-cure treatment with 5-percent solids solution of Permafresh 183.

Control fabrics were woven from starch-sized warp and untreated filling yarns. The control fabrics were desized, scoured, and bleached. Parts of the control fabrics were given a conventional pad-dry-cure treatment using a padding solution containing 6-percent of Permafresh 183. Additional lengths of the control fabric were treated with each of the four polymers and dried. The polyurethane and the butadiene-styrene copolymer pad bath each contained 16-percent polymer solids while the polyacrylate pad-bath contained 12-percent solids. The polymer-treated control fabrics were given a pad-dry-cure treatment using a padding solution containing 5 percent solids of Permafresh 183.

Table 2 shows the strength properties of two fabrics woven from warp and filling yarns pretreated with Polyacrylate E-358 and Polyurethane E-406. These fabrics were compared with the control fabrics which were given the same polymer treatments in fabric form. The results show that the polymer-treated fabrics have substantial improvement over the standard crosslinked fabrics in both breaking and tearing strength. Generally, the yarn-treated samples show a modest improvement over the fabric-treated samples in strength properties. The polyacrylate samples had slightly better strength properties than the polyurethane samples.

Breaking strength retention in the polymer-treated samples was much better in the warp direction than in the filling direction. Warp breaking strength retention after crosslinking for the 16 yarn-treated fabrics ranged from 69 to 104 percent relative to the untreated control. Filling strength retention ranged from 48 to 63 percent relative to the untreat-

Table 2.—Strength properites of fabrics

Property	Yarn treated				Fabric treated	
	Untreated	X-linked Control	Poly-acrylate	Poly-urethane	Polyacrylate	Polyurethane
Breaking strength:						
Warp, pounds	91.8	46.1	73	67.8	67.7	71.1
Filling, pounds	89.8	33.5	51	43.6	45.1	47.4
Tearing Strength:						
Warp, grams	4,666	1,533	2,567	2,233	R[1]	2,367
Filling, grams	4,666	1,267	2,533	1,867	1,733	2,000

[1]Tear reverted to crosswise direction of specimen.

ed control. Although breaking strength retention is usually greater for the warp yarns than for the filling yarns, an even greater difference occurred in this case. The comparative figures for the conventionally finished control were 38 to 51 percent retention in the warp and 32 to 37 percent retention in the filling. The high warp breaking strength retention of fabrics woven from the poly-treated yarns may be caused by the better coverage and polymer orientation achieved in warp sizing under tension. This is not so when the filling yarns are treated in a relaxed state such as skein form.

In table 3, the abrasion properties of polymer-treated fabrics and control-treated fabrics are shown. These data show that polymer-treated fabrics have much better performance than the conventionally crosslinked controls. While the fabrics woven from polymer-treated yarns had somewhat better abrasion resistance than the fabric-treated samples, they also possessed moderately reduced wrinkle recovery angles.

In table 4, wash-wear, crease sharpness and cuff laundry abrasion data for these treatments are presented. The cuffs prepared from the yarn-treated

Table 3.—Abrasion properties and wrinkle recovery angle of fabrics

Property	Untreated control	Control X-linked	Yarn-treated		Fabric-treated	
			Poly-acrylate	Poly-urethane	Poly-acrylate	Poly-urethane
Flex Abrasion (cycles):						
Warp	1,718	52	846	803	599	452
Fill	1,488	42	414	502	318	398
Flat Abrasion (cycles)	481	261	480	565	456	524
Cond. WRA (W+F)	201	308	281	295	309	322

Table 4.—Laundry performance of cuffs with yarn and fabric polymer treatments

Property	Control X-linked	Yarn-treated		Fabric-treated	
		Poly-acrylate E-358	Poly-urethane E-406	Poly-acrylate E-358	Poly-urethane E-406
Wash-wear rating:					
After 1st wash	4.7	4.2	4.7	4.6	4.6
After 30th wash	4.7	4.3	4.4	4.5	4.4
Crease sharpness:					
After 1st wash	5.0	4.3	4.8	4.9	4.8
After 30th wash	4.7	4.3	5.0	5.0	5.0
Avg. laundry cycles to failure	5	46	27	27	16

fabric had properties superior to both the conventional controls and the polymer fabric-treated controls. The cuffs fabricated from the polyacrylate-yarn-treated fabric went 46 laundry cycles before damage, while the cuffs fabricated from the polyacrylate-treated fabric went 27 laundry cycles. Part of this improvement might be due to the lower wash-wear appearance of the cuffs made from the yarn-treated fabric. With the polyurethane-treated cuffs, the improved performance of the yarn-treated cuffs could not be ascribed to this reason since both types of cuffs had equivalent appearance ratings. The polyurethane-yarn-treated cuffs went 27 laundry cycles before damage as compared with 16 laundry cycles for the fabric-treated samples. In this series the conventionally finished control went five cycles before damage occurred.

in the warp and filling, respectively, compared to values of 8.0×10^{-4} and 5.25×10^{-4} in. lb. for the equivalent yarn treated fabric. Similarly, the fabric treated with the second polyacrylate had warp and filling stiffness values of 15.5×10^{-4} and 12.0×10^{-4} in. lb., compared to values of 7.0×10^{-4} in. lb. for the yarn-treated fabrics.

Since lower concentrations of resin appear to be effective with polymer yarn-treated fabrics, lower concentrations of Permafresh 183 were used to determine the resin level necessary to give wash-wear and crease ratings of four or better after 30 laundry cycles. The fabrics were treated to obtain resin add-ons of 3, 3.5, and 4 percent solids using baths containing 10, 12, and 14 percent solutions of Permafresh 183.

Some of the physical properties of the treated fabrics are given in table 5. The appearance and launder performance of these fabrics in test cuffs are given in table 6. It is noticeable that strength properties decrease with progressively higher resin add-ons. This suggests that no higher resin treatment should be used on these fabrics than is necessary to achieve the desired level of appearance and dimensional stability. The results indicate that adequate performance can be achieved with a resin bath containing 5.4 to 6.3 percent solids of Permafresh 183.

Table 5.—Strength properties of fabrics[1] with low resin treatments

Property	Fabrics					
	Polyacrylate E-358 (yarn) Permafresh 183 (fabric)			Polyurethane E-406 (yarn) Permafresh 183 (fabric)		
	10 pct.	12 pct.	14 pct.	10 pct.	12 pct.	14 pct.
Breaking Strength:						
Warp, pounds	83	73	64	84	86	74
Filling, pounds	66	54	45	64	61	56
Tear Strength:						
Warp, pounds	7.2	4.8	4.8	8.1	5.8	5.8
Filling, pounds	5.5	4.0	4.0	5.6	4.8	4.5

[1] Fabrics treated with Permafresh 183.

Table 6.—Yarn-treated fabrics with low resin treatments

Property	Fabric					
	Polyacrylate E-358 Permafresh 183			Polyurethane E-406 Permafresh 183		
	10 pct.	12 pct.	14 pct.	10 pct.	12 pct.	14 pct.
Cond. WRA (W+F)	232	280	269	266	298	287
Avg. laundry cycle to failure	35+	30	25	35+	25	23
Wash-wear Rating:						
1st wash	3.3	3.9	4.0	4.2	4.2	4.7
30th wash	3.7	4.5	4.5	3.7	4.7	4.9

The fabrics treated with polymers at the yarn stage generally had a softer hand than fabrics treated with polymers in the fabric stage. Tinius-Olsen[1] stiffness values were approximately the same with one polyacrylate and a polyurethane. The other polymers showed decided differences. The fabric treated with butadiene-styrene copolymer had a bending moment of 11.5×10^{-4} and 7.25×10^{-4} in. lb.

[1] Federal Specifications CCC-T-191b, Test 5202

Table 7.—Comparison of fabrics with different polymers on warp and filling

Property	Polyurethane (warp) Polyacrylate (fill)	Polyacrylate (warp) Polyurethane (fill)
Cond. WRS (W+F)	285	296
Breaking Strength:		
Warp, pounds	79.4	60.5
Fill, pounds	50.0	46.0
Tearing Strength:		
Warp, grams	3,033	2,267
Fill, grams	2,333	2,153
Stiffness:		
Warp ($X10^{-4}$ in. lb.)	11.0	7.5
Fill ($X10^{-4}$ in. lb.)	10.0	6.5
Flex abrasion:		
Warp, cycles	1,323	413
Fill, cycles	611	306
Wash-wear rating:		
1st wash	4.6	4.5
Crease sharp:		
1st wash	4.3	4.8
30th wash	4.6	5.0
Laundry cycles to damage	42	30

Fabrics with Different Polymers on Warp and Filling.—A number of fabrics with one polymer on the warp and a second polymer on the filling was also investigated. While each of these fabrics had different properties after crosslinking, for the most part, the properties were not unlike the properties of the fabrics woven from warp and filling yarns treated with the same polymer. In table 7, the properties are listed for two finished fabrics. One fabric had polyurethane on the warp and a polyacrylate-treated filling. The second fabric had the reverse treatment of the yarns. The presence of the polyurethane on the filling makes one distinct difference in fabric performance. The polyurethane filling raises crease sharpness of the cuffs to 4.8 after the first wash and 5.0 after the thirtieth wash, compared with values of 4.3 and 4.6 for the reverse fabrics. This is true even though the wash-wear ratings of the two fabrics are approximately the same. By use of different polymers on warp and filling, it appears possible to control fabric properties.

Combination of Temporary and Permenent Sizes

Starch: Warp yarns slashed with an 8-percent solids emulsion of polyurethane were not weavable. Additional yarn was sized with 8-percent polyurethane and resized with a 6-percent thin boiling starch solution. There was no difficulty in weaving these yarns. This fabric was woven with an untreated filling and then desized, scoured, and bleached. One-third of the fabric was padded with a 4-percent solids solution of Permafresh 183. One-third was padded with 8-percent polyurethane and 4-percent solids Permafresh 183. The remaining portion received a treatment of 5-percent polyacrylate K87 and 4 percent solids of Permafresh 183. Cuffs from these fabrics had failures at 20 wash cycles.

Polyvinyl alcohol:—In another experiment, yarns were sized with a 12-percent emulsion of polyurethane, dried, and resized with a 3-percent solution of polyvinyl alcohol. Other yarns were sized with a mixture of a 12-percent polyurethane emulsion and a solution of 3.75 percent polyvinyl alcohol. The resulting formulation was a one-bath sizing mixture of 6-percent polyurethane and 1.8-percent polyvinyl alcohol. Fabrics were woven from these warps with untreated filling, with filling tension sized with 12-percent polyurethane, and with filling tension sized with a mixture of 6-percent polyurethane and 1.8-percent polyvinyl alcohol. A portion of these fabrics was desized and scoured. Each sample was treated with a 5-percent solids solution of Permafresh 183. Other portions of the desized and scoured samples were treated with four different resin formulations. Lengths of the greige or loom run goods were also treated with a 5-percent solids solution of Permafresh 183 without any prewashing or scouring.

The physical properties of the fabrics sized with a mixture of polyurethane and PVA are given in table 8. Scouring before crosslinking reduces fabric breaking and tearing strengths substantially. A comparison with yarn-treated fabrics previously discussed suggests much of the increased strength in this case arises from crosslinking the polyvinyl alcohol into the fabrics. However, despite the fact that warp and filling gray crosslinked fabric had a breaking strength retention of 95 percent in the warp and 85 percent in the filling, cuff laundering performance was poor. The abrasion performance of the cuffs treated by this method was approximately twice that of the control fabric cuffs. The failure to achieve better abrasion performance is probably because the stiffness of the fabrics. Warp and filling stiffness values were 27 $X10^{-4}$ and 19.5 $X10^{-4}$ in. lb., respectively, compared with the usual values of approximately 10-12 $X10^{-4}$ in. lb. for the controls without polyvinyl alcohol.

The fabric woven from yarns sized with polyurethane and resized with polyvinyl alcohol showed

Table 8.—Properties of fabrics sized with polyurethane and polyvinyl alcohol

Property	Fabric			
	Warp treated only		Warp and filling treated	
	Gray X-linked	Scoured X-linked	Gray X-linked	Scoured X-linked
Breaking strength:				
Warp, pounds	62	53	88	61
Filling, pounds	40	29	77	50
Tearing strength:				
Warp, pounds	5.5	4.4	6.0	3.9
Filling, pounds	3.1	2.3	5.4	3.2
Cond. WRA (W + F)	318	301	296	320
Avg. laundry cycle to failure	10	10	12	5
Tinius-Olsen stiffness:				
Warp ($X10^{-4}$ in. lb.)	20.2	12.5	27.0	13.5
Fill ($X10^{-4}$ in. lb.)	7.0	5.5	19.5	8.0

slightly better abrasion properties but lower strength properties than the fabrics woven from yarns sized with a one-bath mixture of polyurethane and polyvinyl alcohol.

Further experiments were conducted in which a mixture of polyvinyl alcohol and polyurethane was used in sizing. The fabrics were given lower level crosslinking treatments using 12-percent Permafresh 183 and 6-percent dimethylol methoxyethyl carbamate. Some of the fabric properties and the laundry performance of the cuffs are listed in table 9. A combination of high wash-wear performance and superior abrasion resistance at a low level of resin add-on has been achieved with this system.

Dye treatments.—To assess the dyeability of fabrics with polymer-treated yarns, commercial denim warp yarns were sized with three different formulations: (1) Conventional starch size; (2) 16-percent emulsion of polyurethane; and (3) one-bath mixture of 8-percent polyurethane and 2-percent CMC. A 10 oz./$yd.^2$ denim fabric was woven from each warp using an untreated filling. Parts of these fabrics were desized, scoured, and bleached. The fabrics were sewn together and dyed with Indanthrene Blue BPWF 70 percent and Ponsol Olive GGLD 14 percent on weight of fabric. All three fabrics dyed level. The control was slightly darker in shade than the two fabrics with polyurethane-treated warps. There was no apparent difference in color shade of the yarn-treated fabrics even though one had twice the polyurethane of the other. Samples were treated with Permafresh 183 and made into cuffs, pressed, cured, and subjected to repeated laundering for evaluation of differences in fading and frosting. When cured, the polymer-treated and control fabrics showed a distinct shade difference. The color change was attributed to the discoloration of the polyurethane. However, the preliminary results suggest that with a proper combination of dye, dye technique and polymer size, the fabrics would be dyeable in fabric form.

Special effects with yarn-treated fabrics.—The polymer yarn-treated fabrics require less crosslinking agent to achieve durable-press performance. This permits the accomplishment of certain special effects if proper selection of fabrics is made. As an example, two-ply yarns were sized with 16-percent polyurethane and woven into a 7 oz./sq. yd. tightweave fabric with polyurethane-treated yarn in both the warp and filling. Three-percent polyethylene was applied to the fabric. The fabric was fabricated into a cuff, pressed, and cured for 10 minutes at 150° C. This cuff had a wash-wear rating of 4.0 and a sharp, acceptable crease after 30 launderings. The wrinkle recovery angle of the fabric was 275° after the first wash. A precure finish using 4.5 percent DMDHEU was applied to another sample of this fabric. The sample was cured, washed, and made into a cuff which was pressed and heat set at 150° C. This cuff had a conditioned wrinkle recovery angle (W + F) of 303°, a wash-wear appearance of 4.5, and a reasonably sharp crease after 30 launderings. The technique seems to work with loosely woven or lightweight fabrics.

An improvement in wrinkle recovery or crease sharpness can be controlled to apply to only one

Table 9.—Tear strength and laundry performance of fabrics

Property	Fabric			
	Warp treated only		Warp and fill-treated	Control
	12 pct. Permafresh 183	6 pct. DMMXEC	12 pct. Permafresh 183	20 pct. Permafresh 183
Tear strength:				
Warp, pounds	5.0	7.05	6.4	3.4
Filling, pounds	3.4	4.8	4.15	3.0
Cond. WRA (W+F)	304	295	289	293
Avg. laundry cycle to failure	20	25	35	7.7
Wash-wear rating:				
35th wash	5.0	5.0	5.0	

Table 10.—Comparison of wrinkle recovery and crease sharpness in polymer-treated fabrics

Treatment	Conditioned Wrinkle Recovery Angle				Crease sharpness 30th wash
	1st wash		30th wash		
	Warp	Filling	Warp	Filling	
					Degree
Conventional	141	139	114	104	62
Fabric polymer treated	160	160	150	148	32
Warp and filling yarns polymer treated	159	162	152	151	27
Warp yarns polymer treated	156	139	152	123	58

[1] All fabrics were padded with 16-percent Permafresh 183, 1-percent polyethylene and crosslinked.

direction of the yarns in the fabric system. For example, table 10 shows that the wrinkle recovery performance of the fabric treated with polyurethane has a similar performance to the fabric woven from warp and filling yarns treated with polyurethane. When the polymer is applied only to the warp yarns, the warp WRA is equivalent to the WRA of the polymer-treated fabric while the filling wrinkle recovery is quite similar to the filling wrinkle recovery value of the conventionally finished fabric without polyurethane.

Analogous performance can be noted in crease sharpness values. The polyurethane-treated yarn fabric and the polymer-treated fabric listed in table 10 have low crease sharpness values of 27° and 32°, respectively. In contrast, fabrics with only the warp yarn polymer-treated have a crease sharpness value of 58°. This value is similar to the conventional finish value of 62°. The method of applying polymer only in the warp gives the advantage of increased wrinkle recovery and abrasion resistance in the warp direction without the increased crease sharpness which occurs when both the yarn systems are polymer-treated or when the fabric is polymer-treated.

SUMMARY

A permanent warp size can be utilized as an integral step in fabric weaving and finishing. Fabrics woven from polymer-treated yarns require a slightly lower level of crosslinking agent than fabrics treated with polymers. Similarly, fabrics woven from polymer-treated yarns usually have slightly better physical properties after crosslinking and offer moderate improvement over polymer-treated fabrics in abrasion performance. In contrast to the fabric-treated samples, application of polymers before weaving frequently lead to softer fabrics at the same level of polymer load.

The weaving of a warp yarn treated with one polymer in combination with an untreated filling or a filling treated with a different polymer leads to unique fabrics that cannot be duplicated by treatment of fabric with polymers. By proper selection of the polymers, a certain amount of tailoring of fabric properties can be accomplished.

In addition to a 100-percent permanent polymer size, several fabrics have been reported on in which a mixture of permanent and temporary sizing agents were used. Starch, CMC, and polyvinyl alcohol have been used as temporary sizing agents in combination with permanent polymers such as polyurethane. This permits the use of a lower level of permanent polymer add-on with good weavability of the warp yarns.

Residual polyvinyl alcohol can be further utilized to improve strength retention in conjunction with a polymer treatment. In one such case, a fabric was produced with 95-percent retention in warp breaking strength and 85-percent retention in filling breaking strength with a WRA of 296°. Despite these strength retention properties, control of fabric stiffness must be achieved before superior abrasion performance is obtained.

Another type of fabric can be produced by use of permanent polymer sizing in the warp only. Such a fabric has increased polymer protection and wrinkle recovery in the warp direction without the increased crease sharpness that occurs when both the warp and fill yarns are treated and when the fabric is polymer-treated.

Certain special effects can be produced with the yarn-treated fabrics. It has been possible to produce two-ply 7-ounce tightly woven fabric with good wash-wear appearance and crease sharpness with only a polymer finish. Furthermore, a low level cross-linking treatment has been utilized to produce a durable-press cuff with acceptable crease performance after 30 launderings. Such a fabric may alleviate the formaldehyde release and alteration problem usually associated with postcure goods.

Finally, initial experiments indicate that fabrics woven from polymer-sized yarns can be dyed in the fabric state.

Research on the use of polymer sizes to improve the performance of durable-press cotton fabrics is continuing; however, a preliminary report of the current findings was deemed desirable at this time.

ACKNOWLEDGMENTS

The authors are indebted to many of their coworkers for the preparation, finishing, and testing of the experimental fabrics. They wish to express their appreciation to all personnel in the Cotton Mechanical Laboratory and especially to M. L. Bocage, N. P. Roddy, and J. J. Landry for the slashing, weaving, and finishing of all fabrics produced in this study. The authors also wish to express their appreciation to the many cooperating members of the Cotton Finishes Laboratory and Textile Testing Investigations for their assistance in finishing and testing of the many experimental fabrics.

---

1. Abrams, E., and Sherwood, N. H. 1953. Nitrile rubber latices as permanent abrasion-resistant finishes for blue denim fabric. Amer. Dyestuff Rptr. 42: 777-782.

2. American Association of Textile Chemists and Colorists. 1965. AATCC Tentative Methods 88a-1964T and 88c-1964T. Tech. Manual 41: B99-103, B104-105.

3. American Society for Testing and Materials. 1966. ASTM D1295-53T, D1682-59T, D1424-59, D1175-55T.

4. Blanchard, E. J., Harper, R. J., Jr., Gautreaux, G. A., and Reid, J. D. 1967. Urethanes improve all-cotton DP. Textile Indus. 131(1): 116-119, 122, 143.

5. Harper, R. J., Blanchard, E. J., and Reid, J. D. 1967. Acrylates improve all-cotton DP. Textile Indus. 131(5): 172, 174, 177, 181, 184, 196, 233, 234.

6. Sherwood, N. H. 1955. Nitrile latices a new concept in textile finishing. Amer. Dyestuff Rptr. 44: P262-P264.

7. Wolfgang, W. G. 1966. Heading to market: Polyurethane resins that boost abrasion resistance. Textile World 116(1): 104-106, 108, 110.

PREPARATION OF FLAME RETARDANT COTTON PRODUCTS

[SUMMARY]

by

J. V. Beninate

Southern Utilization Research and Development Division

New Orleans, La.

During the past 12 years the Southern Regional Research Laboraroty has conducted research aimed at the development of durable finishes to make cotton flame resistant. Valuable assistance in this work has been given by the Office of the Quartermaster General, Department of the Army, the National Cotton Council of America, and other organizations interested in flame resistant cottons. This research led to the discovery and development of several durable flame retardant finishes based on phosphorus and nitrogen compounds, such as the THPC-amide and APO-THPC finishes. The THPC-amide is now being used commercially. These finishes impart flame resistance to cotton, which is durable to laundering and drycleaning, and in addition, imparts dimensional stability, crease-, rot-, and glow-resistance. These finishes have the drawback of being costly, yellowing on bleaching with hypochlorite, and producing stiffness if applied to fabrics of less than 5 oz./yd.^{2}

Very recently a new flame retardant for cotton has been discovered based on the reaction product of THPC and NaOH. It can be applied to cotton from aqueous solution, dried by conventional means, and chemically cured with ammonia. The finish is durable to laundering and drycleaning and can be applied to lightweight fabric to impart flame resistance with essentially no change in fabric properties. More recently selected low-cost N-methylol compounds have been incorporated with tetrakis (hydroxymethyl) phosphonium hydroxide (THPOH) formulations and applied to cotton fabric by a number of different processing techniques. N-methylol compounds evaluated in this study were trimethylolmelamine, dimethylolethyleneurea, and dimethylolmethoxyethyl carbamate.

THPOH reacts with ammonia at room temperature and with methylolamides at elevated temperatures. The flame-retardant finish produced by reacting the phosphonium hydroxide with ammonia is very durable and effective at modest add-ons. Studies have shown that the amount of phosphorus needed in the flame retardant can be reduced to a fraction of that orginally required by increasing the nitrogen content. Use of trimethylolmelamine and THPOH with an ammonia cure followed by a heat cure produced the most effective flame resistance. Treated fabrics had 100-percent tensile strength retention and a good hand. This treatment has resulted in the use of lesser quantities of THPOH to produce a lower-cost durable flame-retardant finish for cotton.

MILD CURE FINISHING PROCESS FOR THE PRODUCTION OF WRINKLE-RESISTANT COTTON FABRICS

by
R. M. Reinhardt, N. A. Cashen, and J. D. Reid
Southern Utilization Research and Development Division
New Orleans, La.
(Presented by R. M. Reinhardt)

INTRODUCTION

A new finishing process has been developed that yields cotton fabrics with high levels of both wet and dry (conditioned) wrinkle resistance. It is a simplified modification of European damp cross-linking technique that appears to be more suitable for American finishing practice. The modified method is called the mild cure finishing process.

BACKGROUND

Moist cure or damp crosslinking techniques have been developed in Europe for producing wash-wear cotton fabrics with high wet and dry wrinkle resistance. Dry wrinkle resistance is developed by these finishing methods only when certain critical conditions of treatment are met, namely, closely controlled moisture content in the fabric during a relatively long reaction period. The combination of high dry wrinkle recovery and high wet wrinkle recovery is particularly important to give fabric with good smooth dry appearance when no tumble dryer is available and line drying is necessary.

A study of damp crosslinking was undertaken at this Laboratory and has led to the development of the mild-cure finishing process. Modifications have been made that permit elimination of the long treatment period of the European processes. Instead, a simple, mild cure treatment step has been substituted as the only processing operation necessary other than padding, washing, and drying.

The present paper described the new, mild cure finishing process and outlines the effects of the variables of the process. Properties of the products also are described and some comparison with those of conventionally finished cotton is provided. The theoretical basis of the process from chemical and physical observations are considered.

EXPERIMENTAL AND RESULTS

Most experiments were carried out on 80 x 80 cotton printcloth with carbamate finishing agents. Dimethylol methyl carbamate (DMMC) was used to study the effect of processing variables. No softener or other auxiliary agent was used in the treatments.

Standard test methods and analytical procedures were employed to characterize the finished cotton.

The mild cure finishing process consists essentially of the following steps:

(a) Impregnating the fabric with an aqueous solution containing a cellulose crosslinking agent and a strong mineral acid catalyst.
(b) Heating the impregnated fabric under mild conditions for a relatively short time without prior drying.
(c) Neutralizing and washing the treated fabric.
(d) Drying the washed fabric.

The treatment appears to be amenable to continuous processing as is diagramed in figure 1. However, in this study, it has been carried out in batch steps on a laboratory and semi-pilot plant scale. In the pilot plant, for example, cotton printcloth was padded to approximately 80-percent wet pickup with a solution containing 10-percent DMMC and 0.37-percent hydrogen chloride (1 percent hydrochloric acid), and cured on the tenter frame at 60° C. with a dwell time of 6 minutes and 40 seconds. The fabric had a moisture content of 4 to 5 percent after this treatment. After neutralization, washing, and drying, analysis of the treated fabric showed 0.64-percent nitrogen and 2.10-percent formaldehyde content. This indicates a molar ratio of HCHO/N of 1.53 in the treated fabric which is essentially equivalent to that generally found in fabric finished with the same agent in conventional pad-dry-cure treatments. Breaking strength of the treated fabric was 31 lb. which is 65 percent of that of the untreated. Conditioned wrinkle recovery was 265° (W + F); wet wrinkle recovery, 273°. Smooth dry ratings by the AATCC overhead lighting method after tumble drying and line drying were 4.3 and 4.7, respectively.

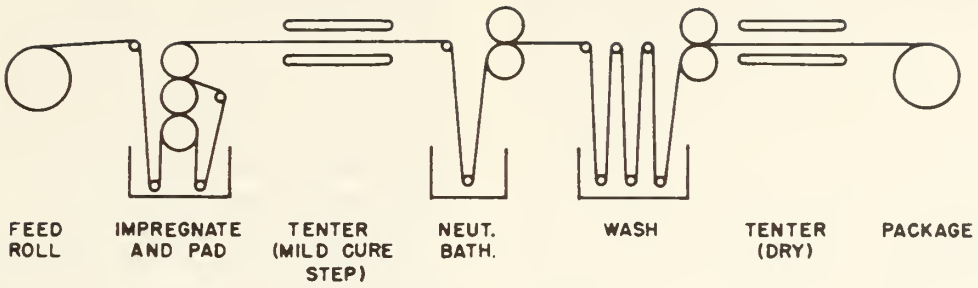


Figure 1.—Diagram of mild cure finishing process.

In recent experiments, it has been found possible to further accelerate the curing step. Curing on the tenter frame at 100° C. for 2 minutes produced a finished fabric with similar smooth drying properties and strength.

In laboratory experiments to investigate the variables of the process, impregnated fabrics were placed in pin frames, cured in a forced-draft oven, then neutralized, washed, and dried.

Printcloth impregnated with a solution of 10 percent DMMC and 0.37 percent hydrogen chloride was heated for various times at 40, 60, and 80° C. (fig. 2).

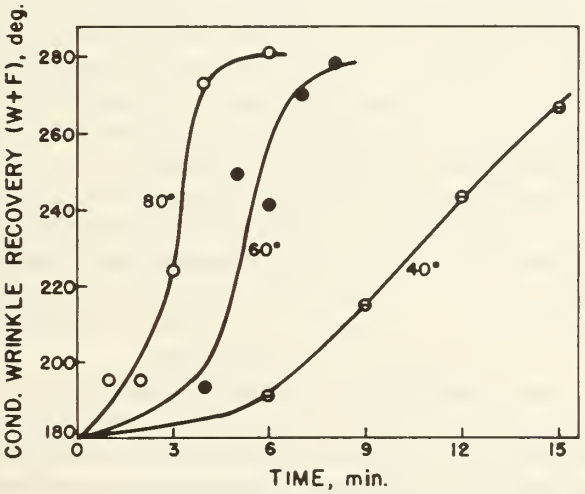


Figure 2.—Heating temperatures.

Wrinkle recovery angles obtained indicated that improved wrinkle resistance correlated with loss of moisture and approach of the leveling-off moisture content characteristic of the treatment temperature. The latter is indicated from the drying curves shown in figure 3.

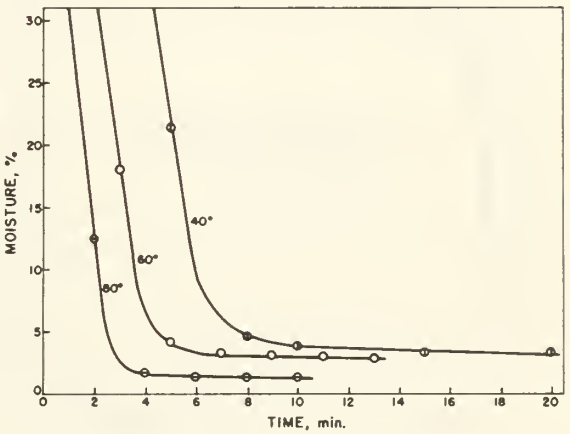


Figure 3.—Drying curves.

The level of wrinkle resistance attained appeared to be related to the moisture content of the fabric. That is, high moisture contents during the mild cure treatment step inhibited the development of high levels of conditioned wrinkle resistance. This relationship is similar to that reported for the European damp crosslinking process. However, in the present process the moisture level need not be maintained for such extended periods as in the European process.

Strength of the treated fabric varied as a function of the time of the cure. Thus, there is a point at which there is no further improvement in wrinkle resistance but which is followed by progressive loss of strength. Therefore, an optimum relationship between strength and wrinkle resistance is achieved at the point at which the wrinkle resistance values

level off. At 80° C., this point was observed at about 5 minutes' curing time, at 60° at about 7 minutes; and at 40° at more than 15 minutes' curing time.

The time-temperature curing relationship is altered for fabrics of other weights and structures and for other curing equipment. In addition to printcloth, treatment of sateen, oxford, and twill has been investigated.

Correlation of the drying curves, chemical analyses, and wrinkle recovery angles indicates that in mild cure finishing, reaction between DMMC and the cotton begins while the fabric is still wet. However, dry wrinkle resistance is not effectively improved until the moisture is reduced below about 5 percent.

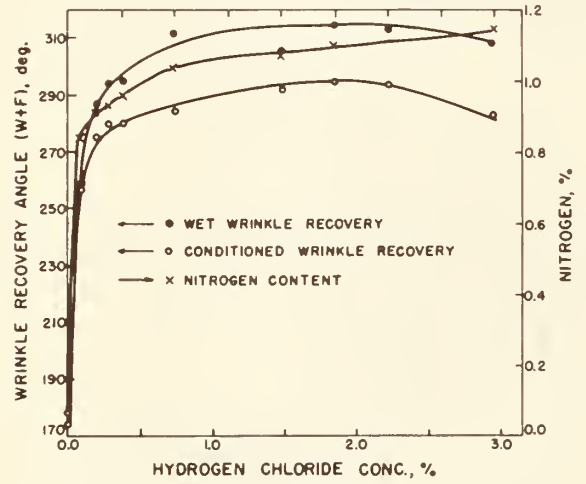


Figure 4.—Effect of catalyst concentration.

The effect of catalyst concentration (0.1- to 3-percent hydrogen chloride) upon treatment of printcloth with 15-percent DMMC by the mild cure process is shown in figure 4. Samples were cured for 7 minutes at 60*J* C. with various concentrations of catalyst. Catalyst concentrations of 0.2- to 0.5-percent hydrogen chloride appeared to be optimum as judged by strength and wrinkle recovery properties. For catalyst concentrations below about 0.8-percent hydrogen chloride, strength varied as a function of the level of wrinkle resistance of the fabric. With higher catalyst concentrations, greater losses of strength resulted with only small further increases in wrinkle resistance. Bound nitrogen content of the treated fabrics increased as a function of catalyst concentration. Wet and dry wrinkle resistance increased with catalyst up to about 2-percent hydrogen chloride concentration, above which slightly lower values were observed. Wet wrinkle resistance were about 12° to 20° higher than conditioned recoveries for most treatments.

Other mineral acids could be employed as catalysts. Nitric and sulfuric acid provide effective catalysis at concentrations equivalent to those demonstrated with hydrogen chloride. Other acids, among them phosphoric, oxalic, citric, and tartaric, were tried as catalysts but were ineffective under the mild cure processing conditions.

Pad baths of 5 to 20 percent DMMC with 0.37 percent hydrogen chloride catalyst were used to study the influence of the concentration of crosslinking agent in the treatment. Curing was for 7 minutes at 60° C. The reaction efficiencies of these mild cure treatments were about 60 percent as calculated from the nitrogen content of the finished fabrics. The reaction efficiency in conventional pad-dry-cure treatments also is generally about 60 percent.

Improvement in wrinkle recovery is a function of crosslinking agent concentration but levels off with high concentrations. Wet wrinkle resistance levels off at higher concentrations than does dry wrinkle resistance. Tearing strength is decreased by the treatment but varies only slightly with concentration of agent used.

All of the common dimethylol carbamate agents were used in the mild cure finishing process. These included the dimethylol derivatives of methyl, ethyl, isopropyl, methoxyethyl, hydroxyethyl and hydroxypropyl carbamate. All performed well. Dimethylol hydroxyethyl carbamate, which generally requires stronger catalysis and reaction conditions than the other carbamate agents in pad-dry-cure finishing, functioned as well as in the mild cure process as the more reactive homologues.

N-methylol agents of other classes were investigated and many can be employed in the mild-cure process. Effectiveness varies with the nature of the agent. In general, the order of effectiveness is approximately the reverse of the order of reactivity in conventional pad-dry-cure finishing.

Urea-formaldehyde cannot be used because it polymerizes in the presence of the strong catalyst. Dimethylol ethyleneurea and dimethylol propyleneurea give relatively poor results but may work better with other modifications of the treatment conditions. Dimethoxymethyl uron and dimethylol dihydroxyethyleneurea can be employed successfully. A modified propyleneurea agent, dimethylol 4-methoxy-5, 5-dimethyl propyleneurea, also gave good results.

It appears that agents which yield finishes that are

resistant to acid hydrolysis perform better in the process than fast-reacting agents that give finishes that are not so acid-resistant.

FABRIC PROPERTIES

In general, the properties of fabrics processed by the mild cure finishing method are equivalent to those of fabrics finished by conventional pad-dry-cure treatment. Some of the properties are apparent from the preceding discussion.

High levels of wet and dry wrinkle resistance are produced which result in fabrics that have high smooth dry ratings after tumble, drip, or line drying. The relationship between strength and wrinkle resistance and the stress-strain relationship is about the same as in pad-dry-cure finishes. Similarly, abrasion resistance as measured by the Stoll flex test is about the same as in pad-dry-cure finishes. Resistance to chlorine damage however, is poorer in fabrics processed by mild cure finishing. Moisture regain of mild cure fabric is slightly greater than that of pad-dry-cure fabric. Durability to laundering is as good as in products of pad-dry-cure finishing.

Electron micrographs were prepared from specimens of cotton fabric finished with DMMC by the mild cure process and by the pad-dry-cure process. The fabrics selected for study had equal conditioned wrinkle recovery angles and nitrogen contents. Equivalence of the treatments at the microscopical level was indicated by the effects of layer expansion and cuene solubility techniques on ultrathin sections. From these microscopical studies it was concluded that a high degree of crosslinking is produced uniformly throughout the fiber by mild cure processing. Also, the mild cure conditions are sufficient to give a crosslinked structure which appears to be equivalent to that produced by the more stringent conditions of conventional pad-dry-cure finishing.

MECHANISM OF REACTION

The crosslinking reaction in mild cure finishing is believed to proceed by a carbonium ion mechanism as depicted in figure 5. Protonation of the methylol moiety of the finishing agent by the strongly acidic catalyst, followed by loss of water, yields the carbonium ion which is stabilized by resonance with an immonium ion structure. Reaction of cellulose with the carbonium ion gives a protonated cellulose intermediate which then loses the proton to yield the modified cellulose derivative. Similar reaction through the second methylol group gives the crosslinked cellulose.

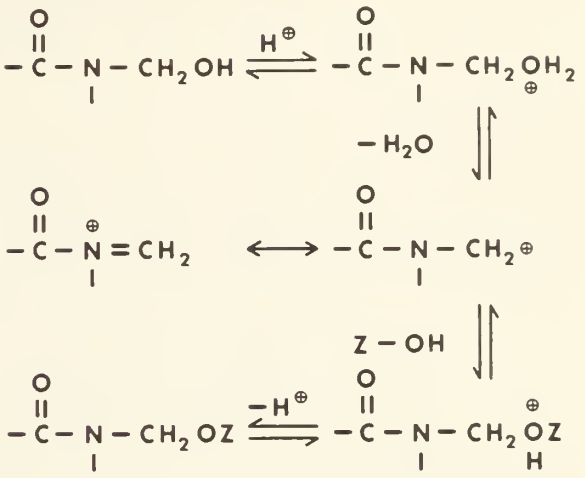


Figure 5.—Mechanism of reaction

Each step of the mechanism involves a reversible reaction. The rate determining step appears to be that in which water is eliminated as the leaving group from the protonated methylol compound to generate the carbonium ion. With the mineral acid catalyst used, the overall reaction apparently proceeds readily under the mild cure conditions. In pad-dry-cure finishing, catalysis is generally provided by a salt that is a Lewis acid rather than by protonation with mineral acid. Stronger curing conditions are required to affect reaction.

The apparent difference in reactivity of various agents in the two finishing processes also can be explained by this mechanism. In pad-dry-cure finishing, the Lewis acid salt catalysts provide weaker catalysis, and thus this type of finishing works best with highly reactive agents. A high level of acid stability by the finish is not necessary since reversal of the crosslinking reaction requires the presence of water. Water is not available as it is driven from the fabric at the high temperatures of curing.

In mild cure finishing, the strong catalysis and partial removal of water drives the reaction forward even with relatively less reactive agents. However, only linkages that are highly acid resistant can survive because of the presence of the acid and moisture in the fabric during the treatment.

SUMMARY AND CONCLUSIONS

A process that employs a simple, mild cure treatment step has been developed for finishing cotton to impart high levels of wet and dry wrinkle resistance. Cotton fabrics of several weights and structures have been treated by the process to yield textiles that dry smoothly after either tumble-, drip-, or line-drying.

The effects of the variables of the mild cure finishing process—principally the nature and concentration of the crosslinking agent and catalyst employed, and the time and temperature of the cure—have been determined and their interrelation indicated. Not all of the usual crosslinking agents are applicable in this process. Dimethylol carbamate agents are particularly suitable. Hydrogen chloride (from hydrochloric acid) provides effective catalysis under the mild curing conditions employed. Other strong mineral acids also may be used. Treatment conditions must be modified for different fabrics and for different processing equipment.

The properties of cotton finished by the mild cure process are essentially equivalent to those of fabric treated by conventional pad-dry-cure treatment. The principal exception to this generalization is a higher level of wet wrinkle resistance in conjunction with high dry wrinkle resistance. This extra measure of wet wrinkle resistance produces a considerable increase in smooth drying performance after drip- or line-drying as compared with fabrics from conventional finishing. The latter generally exhibit high smooth dry ratings upon tumble drying but are less satisfactory when dried by other methods.

The crosslinking reaction in mild cure finishing is believed to proceed by a carbonium ion mechanism following protonation of the methylol moiety of the crosslinking agent by the strongly acidic catalysts used. Apparently, this mechanism is operative with relatively moderate curing conditions and without the necessity of extensive dehydration of the fabric in the treatment. Chemical and physical evidence support the mechanism proposed.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of the following colleagues who have aided in the study: John S. Mason and Ann Black, for chemical analysis; Marilyn M. Smith, Constance F. Cashen, Mary F. St. Cyr, and others of the Textile Testing group for some of the tests; and Jarrell H. Carra for the electron microscopy.

PRE-CURE DURABLE PRESS FINISH THROUGH THE USE OF POLYMER DEPOSITION

by
H. H. St. Mard, C. Hamalainen, W. A. Reeves, and A. S. Cooper, Jr.
Southern Utilization Research and Development Division
New Orleans, La.
(Presented by H. H. St. Mard)

A promising approach for developing a satisfactory durable press finish for all-cotton fabric involves limiting the extent of crosslinking in combination with deposition of polymer or within the cotton fibers, or both. The Poly-Set process which consists of two steps is an example of such an approach.

This Poly-Set process[1] is responsive to lubricant and softener additives and it was noted that when certain of these were used with zinc acetate as catalyst in the first step of the process; fabrics with very high wrinkle recovery angles were produced. Also of prime importance these fabrics retained very high tensile, tear, and abrasion resistance.

It was decided to pursue the theory that a one-step process could be developed for treating lightweight fabrics such as shirts and sheets. The plan was to determine the optimum conditions of cure time and temperature, resin type, etc., for such particular end uses.

A 2-minute cure at 160° C. resulted in sheeting fabric with retention of 65-percent tensile and 75-percent tear strength and with a wrinkle-recovery angle of 293°. The resin formulation consisted of a 10-percent solids concentration of equal parts of a modified methylolmelamine (MMM) and dimethylol propylene urea (DMPU) in combination with a 4-percent polyurethane and 1.2-percent olefinic softener. The catalyst was 5-percent zinc acetate.

Both broadcloth and sheeting fabrics treated with equal parts of a mixture of MMM and DMPU had much better smooth drying properties than when these fabrics were treated with these resins individually. Also, the other physical properties were considerably better than those of conventionally catalyzed controls.

The use of a latent acid catalyst, such as zinc nitrate, in conjunction with the zinc acetate produces fabric with much higher wash-wear rating and wrinkle-recovery angle than does the use of zinc acetate alone. Reducing the amount of zinc nitrate in this combination causes a reduction in wash-wear rating with a corresponding increase in flux, tear, and tensile strength with no significant change in wrinkle-recovery angle. The combination of 2-percent zinc acetate and 0.5-percent zinc nitrate as catalyst produces the best overall results. Sheeting was treated with the resin combination (MMM-DMPU) in which both 5-percent zinc acetate and 2-percent zinc acetate with 0.5-percent zinc nitrate were separately used as catalysts. One formulation contained only the olefinic additive and the other contained both the olefin and the polyurethane. For both catalysts the addition of polyurethane caused an increase in flex abrasion, higher breaking strength, slightly lower tear strength, and higher wrinkle recovery angle which was particularly evident in wet-wrinkle recovery. Use of zinc acetate, zinc nitrate mixed catalyst produced a small improvement in smooth drying performance, but at some sacrifice in physical properties.

The use of this urethane caused some yellowing of the fabric after a home laundry and tumble dry test which indicates that it would be unsuited for white goods. Subsequent additional washes including hypochlorite bleach resulted in further yellowing of the samples with urethane additive and also some yellowing in the other treated samples not containing urethane.

Recent work by this process using other resins without this urethane had produced promising results in treating fabrics for good smooth drying properties without yellowing from chlorine bleaching. This indicates that by proper selection of resins and additives fabrics could be produced by this process for such end uses as shirts and sheets.

[1] Reeves, W. A., Hamalainen C., St. Mard, H. H., and Cooper, A. S., Jr. Poly-set process for producing durable press cotton goods. Textile Res. Jour. 37: 76-88. 1967

BASIC ASPECTS OF THE CROSSLINKING OF COTTON

by
S. P. Rowland
Southern Utilization Research and Development Division
New Orleans, La.

SUMMARY

The ability of cotton to undergo chemical modifications for the development of wrinkle resistance, durable press, flame resistance, etc. is dependent primarily upon the multitude of hydroxyl groups that are present and available in the cellulose molecules. On the other hand, the performance properties of cotton fabrics, both before and after chemical modification, depend upon the structure of the cotton fiber as a long hollow tube composed of a multitude of highly crystalline microstructural units. This paper brings together the results of recent studies in order to develop a better understanding of the complexities of interactions between chemical and physical factors in the crosslinking of cotton cellulose.

Cotton cellulose in the form of fabric is subjected to crosslinking reactions for dimensional stabilization and for easy-care and durable-press performance. These characteristics are developed as a result of chemical reactions which occur deep in the fiber structure of the cotton cellulose and which impose physical restraints on the microstructural units in the fiber. In a discussion of the crosslinking of cotton, it is necessary, therefore, to consider the chemistry of the crosslinking, to appreciate the effect that the physical state of the cellulose has upon the chemistry of the crosslinking, and to remember that the chemical reaction is conducted for a specific physical effect in the fiber.

The cotton fiber is a complex, well-ordered unit which is generated during the growth cycle of the cotton plant in the form of a long, hollow tube, approximately 20 microns in width by 25,000 microns (1 inch) in length. Each fiber, a section of which is shown in figure 1A, is composed of a multitude of microstructural units which are packed in close proximity and which are "microfibers" or fibrils. These become evident when an expanded part of a cross section of a cotton fiber is examined under high magnification, as in electron micrograph (figure 1C). The surface of a slab torn out of the cotton fiber (figure 1D) shows the fibrils, at high magnification, in an arrangement which they have in the fiber. These fibrils are composed from cellulose molecules which consist of more than 3000 *D*-glucopyranosyl units, (fig. 1E), joined together into a linear chain. The ability of the cotton to undergo crosslinking reactions is dependent upon the multitude of hydroxyl groups that are present in the cellulose molecule.

The hydroxyl groups in cotton cellulose, upon which we depend for the crosslinking reactions and for the development of performance properties, are buried in a catacomblike labyrinth in the cotton fiber. Only a fraction of these potential sites for chemical reaction are actually accessible to the reagent. Moreover, there are three different kinds of hydroxyl groups in the fibers of cotton cellulose, that is, those at carbon atoms 2, 3, and 6 of each *D*-glucopyranosyl unit (figure 1E). These three different hydroxyl groups react at different rates and the linkages developed exhibit different stabilities. The science of the crosslinking of cotton fibers then appears to reduce to the selection of the appropriate chemical reagent, control of the penetration of the reagent into the fiber to the accessible hydroxyl groups, and control of the reactions with specific hydroxyl groups to develop the desired physical performance characteristics.

The first question that we might consider is: How does the chemical reagent reach the hydroxyl groups in the bulk of the fiber? While the cross section of the native fiber or a mercerized fiber shows no pores or channels even at the high magnification of an electron micrograph, the cross section of a swollen fiber, after embedment in methacrylate polymer (*25*), exhibits a selective concentric expansion with the development of pores, such as shown in figure 1B. The expansion and pore development, which the fiber undergoes in aqueous solutions of crosslinking agents, is probably of the same type but considerably lesser in degree. The pores of decrystallized cellulose have been estimated by gel permeation chromatography to accommodate molecules of sugars ranging downwards in molecular weight from approximately 1,800 (*17*). Molecules having molecular weights slightly below 1,800 find very few pores of adequate size but with decreasing molecular weight of the reagent, an increasing number or volume of

Figure 1.—Features of the cotton cellulose fiber that are involved in the crosslinking reaction: *A*, A section of fiber; *B*, an electron micrograph of an expanded cross section of a cotton fiber; *C*, a portion of the expanded cross section under highest magnification; *D*, an electron micrographic view of the longitudinal structure and fibrils in a slab torn from a cotton fiber; and *E*, two *D*—glucopyranosyl units which constitute a part of the molecular chain of cellulose.

pores will accommodate the reagent. Preliminary measurements on fibrous cotton have resulted in numerical values of the same order of magnitude[1] It is quite evident, then, that the normal type of crosslinking agent, which has a molecular weight in the range of 100 to 200, finds many pores or channels through which it may reach the hydroxyl groups of the cellulose molecules in the microstructural units.

At this point, our consideration of the crosslinking reaction brings us to the question: How are the microfibrils involved in the chemical reactions? An elegant and introspective study of the course of the exhaustive methylation of cotton cellulose in non-mercerizing base (that is, 2*N* NaOH) with dimethyl sulfate led the investigators *(11, 13)* to propose that a rapid phase of the reaction occurred with the hydroxyl groups on the surfaces of microstructural units and that a slower phase of the reaction involved hydroxyl groups which were beneath the surface and which were reached by gradual penetration of the reagent into the microstructural unit. It was noted that at the point corresponding to the end of the rapid reaction that 56 percent of the *D*-glucopyranosyl units were unmethylated, that is, inaccessible in the interior of the microstructural unit. The number of accessible and inaccessible *D*-glucopyranosyl units on the surface and in the interior, respectively, correspond closely to that of a structural unit having a rectangular cross section composed of 8 stacks of *D*-glucopyranosyl units, each stack being 12 units deep. The lateral dimensions of this microstructural unit are estimated to be approximately 50 Å by 50 to 100 Å, which is consistent with the dimensions of the smallest structural units, that is, the elementary fibril, which have been measured in electron micrographs.

Several elementary fibrils, in ordered lateral arrangement, make up a larger structural unit *(34)*, such as those shown in figure 1C and D and referred to earlier as fibrils. It is most interesting, then, that exhaustive methylation of cotton fibers from a medium having limited penetrating capacity into the fibers, that is, diazomethane in moist ether *(11, 13)*, resulted in 73-percent inaccessibility of the *D*-glucopyranosyl units at the end of the rapid phase of the reaction. This approximates expectation for a reaction occurring on the surface of a fibril formed from the perfect lateral packing of four elementary fibrils.

It is quite pertinent to our picture of the involvement of the microstructural units in crosslinking reactions to note that base of mercerizing strength swells and penetrates into the highly ordered (or crystalline) structure of the elementary fibrils *(35)*. When the reagent is present in a mercerizing medium, reaction occurs with *D*-glucopyranosyl units within the interior of the elementary fibril. The extent and uniformity of the penetration and reaction of the reagent within the elementary fibril is dependent upon the nature of the reagent, the concentration of the mercerizing base, and, perhaps, other factors *(30)*.

Now, our concern about the crosslinking reactions of cotton cellulose may be reflected in the question: What controls the reactions of the three different types of hydroxyl groups at C-2, C-3, and C-6 in the *D*-glucopyranosyl units, and to what extent are these different? Recently obtained evidences *(3, 32)* indicate that the three different types of hydroxyl groups are accessible in a selective manner on the surfaces on the microstructural units. In non-mercerizing base (1 & 2*N*) the accessibility in native fibers appears to be in the ratio of 1.00:0.30:0.75 for the hydroxyl groups at C-2, C-3, and C-6, respectively. In fibers that have been subjected to mercerization, the ratio of accessibilities is 1.00:0.65:0.65. These results were obtained by studying the distributions of substituents introduced into the *D*-glucopyranosyl units of cotton cellulose in homogeneous solution (in benzyltrimethylammonium hydroxide), in mercerizing media, and in various non-mercerizing media *(3, 32)*.

When a reaction of cotton fibers is conducted in a mercerizing medium (rather than subsequent to mercerization), the hydroxyl groups at C-2, C-3, and C-6 on a specific *D*-glucopyranosyl unit become equally accessible *(32)*. Under these conditions, the distribution of substituents is a function of the relative reactivities of the hydroxyl groups in the case of irreversible reactions and a function of a combination of relative reactivities and relative thermodynamic stabilities of the substituent linkages in the case of reversible reactions. Irreversible reactions of the hydroxyl groups of cellulose are exemplified by the Williamson etherification summarized in table 1.

In general, in these reactions the hydroxyl groups exhibit relatively similar reactivities, the secondary hydroxyl group at C-2 being approximately 0.7 to 3 times as reactive as the primary hydroxyl group at C-6 and the secondary hydroxy group at C-3 being approximately 0.15 to 0.45 times as reactive as that at C-6. The lack of constancy of the relative reactivities of the hydroxyl groups through this series of

[1] Martin, L. F. Private communication.

reagents provides evidence that size of the reagent molecule or the resulting substituent is important. As the size of the reagent increases, the proportion of reaction of the hydroxyl group at C-2 decreases. It is interesting that this simple generalization regarding size of the reagent molecule (or the substituent introduced) appears applicable only in a series of reactions proceeding by the same mechanism. A change in reaction mechanism allows the larger 2 (diethylamino)-ethyl substituent to be introduced in greater proportion in the 2-0-position than the 2-aminoethyl substituent; the former substituent from reaction of 2(diethylamino)ethyl chloride proceeds through a smaller and less sterically hindered intermediate (the N,N-diethylethylenimmonium ion) than that involved in the SN2 reaction of sodium 2-aminoethyl sulfate.

Table 1.—Relative reactivities of the hydroxyl groups of cellulose in irreversible reactions[1]

Reagent	K_2K_6[2]	K_3K_6[2]	Reference
Methyl chloride	2.79	0.46	(11)
Ethyl chloride	2.39	0.46	(12)
Dimethyl sulfate	1.85	0.45	(13)
2 (Diethylamino) ethyl chloride	1.27	0.35	(14)
Sodium-chloroacetate	0.75	0.34	(15)
Sodium allyl sulfate	0.7	0.2	(16)
Sodium 2-aminoethyl sulfate	0.64	0.14	(17)

[1] All of these reactions were conducted with sodium hydroxide of mercerizing concentrations.

[2] k_2k_6 designates the rate constant for reaction of the hydroxyl group at C-2 relative to that at C-6. These were obtained from the ratio of the substituents at these positions in the monosubstituted *D*-glucopyranosyl units from reactions carried to low degree of substitution (ca. 0.8 max).

Distributions of substituents at the 2-0-, 3-0-, and 6-0-positions of the *D*-glucopyranosyl units which result from reversible reactions are quite different from those noted above. In these cases (see first set of entries in table 2), the relative distributions in the 2-0 position are below 0.5 and those in the 3-0-position are near 0.1. The opportunity allowed for the reaction to reach equilibrium has a pronounced bearing on the distribution. As shown in studies with the reagent, methyl vinyl sulfone (*3*, *26*) (see second set of entries in table 2), the relative distributions at the 2-0- and 3-0-positions are very low when equilibrium is attained, (ca. 0.1:00.05:1.0), accounting for less than 15 percent of the substituents. However, under conditions allowing little opportunity for equilibrium to be attained (rapid cure at 140° C.) more than 40 percent of the substituents are in the 2-0-position and the distributions of the substituents can vary that which characterizes products from irreversible reactions.

Thus, the answer to the question under consideration is that the reactivities of the hydroxyl groups and the distributions of the substituents can vary substantially as a function of the nature of the reaction, the size of the reagent molecule, and the extent of equilibrium attained.

The discussion of this point has dealt with the site of reaction in the cotton cellulose fiber. Relatively little would remain for consideration if crosslinking reagents underwent reactions to introduce simple monomeric intermolecular linkages between molecules of cellulose. However, crosslinking agents are almost invariably capable of a multitude of digressions from the intended purpose. For example, (a) cyclic structures may be developed on a single molecule of cellulose, (b) substituents may result from lack of reaction of the second functional group with cellulose, and (c) the intermolecular crosslinkings, the cyclic structures, and the substituents may involve more than one unit of the reagent. The next pertinent question is then: Can the number of intermolecular crosslinkages in cellulosic compositions be measured?

The unique aspects involved in enumerating crosslinkages dispersed throughout a crystalline, fibrous polymer have negated applicability of almost all methods that have been considered to date, including those methods developed for rubbers and synthetic polymers. However, an adaptation of the sol-gel analysis, originally developed for synthetic polymers crosslinked by irradiation (*1*), has provided a measure of interesting differences among formaldehyde-crosslinked cotton celluloses prepared by a variety of processes (*29*). Subsequent studies have clarified the applicability of the method to crystalline fibrous cellulose *(15)* and provided a verification of the numerical results by isolation of the structural units involved in the crosslinkages of cotton cellulose modified with tris (1-aziridinyl) phosphine oxide (*31*). It appears, therefore, in certain cases that sol-gel analyses provide a reasonably valid estimate of a number of crosslinkages which are effective in insolubilizing the cellulosic structure in cupriethylenediamine hydroxide. An interesting outcome of the study of formaldehyde-crosslinked cotton celluloses is the number of moles of for-

maldehyde estimated to be required for the development of a single effective crosslink: for example, 3 for an aqueous wet-cure reaction, ca. 9 for the pad-dry-cure process and for a vapor process, and ca. 14 for a second aqueous wet-cure reaction. The requirement of more than one mole of formaldehyde per effective crosslink may be due primarily to cyclic structures and to more than one unit of reagent in the linkages.

At this point we ask: What are the lengths of crosslinkages in cotton cellulose? Estimates of the length of the linkages in cotton cellulose modified with dimethylolethyleneurea led to the conclusion that the linkages averaged ca. 1.5 reagent units long *(8)*. The value was based on the formaldehyde and nitrogen contents of the cellulose composition. More rigorous estimates of the average length of oxymethylene linkages in formaldehyde-modified cotton celluloses indicate that these generally fall in the range of 2.0 to 2.5 units long *(9, 10)*—that is, 2.5 for an aqueous wet-cure reaction; 2.5 for reaction in a predominantly non-aqueous medium; 1.7 for a vapor phase process; and 1.1 for the reaction of potassium methylenedisulfate in the presence of alkali.

As the final question in this test, we ask: Have cyclic structures, substituent groups, or other structural units (than those already discussed) been identified in crosslinked cotton cellulose? Neither cyclic structures nor substituent groups (of any length) have been proved to be present in crosslinked compositions, although the probability of the presence of at least the latter appears high. "Resinified" material may be expected in certain cotton celluloses modified with N-methylol compounds; but, this also has not been identified to date. Recent studies have shown that aminoethylated cotton cellulose has approximately 50 percent of the nitrogen in a form other than simple 2-aminoethyl substituents: That is, as ethanolamine and polyethylenimine residues fixed to the cellulose through substantivity or reaction or both with carbonyl groups *(22)*. Similarly, cotton modified with tris (1-aziridinyl) phosphine oxide was found to be characterized by few ether linkages between the aziridinyl residues and the cellulose *(23, 24, 31)*. Substantial "resinification" or polymerization among the aziridinyl units formed polyethylenimines with attached phosphorus residues. It is important, therefore, that each type of chemically modified cellulose be considered for its own specific peculiarities, in addition to conventional structural units such as those already discussed.

It is quite evident that the crosslinking of cotton cellulose is abundant in ramifications. However, the research, which has been conducted over a period of years to clarify the chemistry of cotton cellulose and the structure of crosslinked compositions, now appears to be reaching a more fruitful stage. Several techniques, such as chromatography (*2, 17, 27*) and mass spectrometry (*10, 19*), which are responsible at least in part for recent advances, are still undergoing development. These techniques promise to facilitate new insights into the complex interactions between chemistry and physics in the cotton fiber.

While more extensive information and more intensive detail are needed along the general lines discussed in this report, information pertaining to the number of crosslinkages and to the structures of the reagent residues in the crosslinked cotton celluloses is particularly desirable. Important factors in the extension of current techniques for this purpose are (a) a solvent for cellulose which may be employed for sol-gel analyses without degradative effects on acid or base sensitive crosslinkages, (b) a method for degrading the molecular chain of cellulose down to (substituted) cellobiose or *D*-glucopyranose units without affecting the reagent residues or their linkages to the *D*-glucopyranose units, and (c) more effective means of separating, identifying, and quantitatively measuring the multitude of reagent residues in the form of substituted and crosslinked *D*-glucopyranose units.

The larger problem of relating process variations to changes in a specific structural feature in the fiber, and, in turn, to specific performance characteristic constitutes the real objective of studies such as those summarized in this report. An appreciation for the complications involved may be gained from a recent exploration of these relationships for cotton cellulose crosslinked with divinyl sulfone (*28*). In spite of these complications, preliminary progress has been made in relating (a) the process of crosslinking to the gross homogeneity of crosslinkages in the fiber cross section (that is, homogeneous or peripheral distribution) to performance properties (*14, 16, 36*) and (b) the process of crosslinking to degree of penetration of the reagent (and crosslinkages) into the microstructural units and to the performance properties *(28)*. It is important to note, however, that in the latter case the structure of the reagent residues is believed to vary concurrently. Evidence from this same study *(28)* suggests that the structure of the reagent residues may be one of the most important factors in the development of a superior balance of performance properties in the fabric; for example, the relation of resilience to strength.

Table 2.—Distributions of substituents resulting from reactions of the individual types of hydroxyl groups of cellulose in reversible reactions.

Reagent	Reaction conditions	Distribution of substituents 2-0-/6-0-	3-0-/6-0-	Reference
Methyl vinyl sulfone	20 pct. reagent 10 pct. NaOH, 25° C, 1 hr.	0.20	0.03	(18)
Acrylamide	ca. 20 pct. NaOH 4° C, 73 hr.	0.47	0.05	(19)
Formaldehyde[1]	aqueous formalin, conc. hydrochloric acid, 20° C, 30 min.	0.38[2]	0.10[2]	(20)
*	*	*	*	*
Methyl vinyl sulfone	25° C, 24 hrs.[3]	0.14	0.05	(21)
	25° C, 1 hr.[3]	0.22	0.05	(21)
	140° C, 5 min.[3]	0.75	0.00	(21)

[1]Distributions resulting from other conditions of reaction fell in this same general range.

[2]Only the distribution corresponding to monosubstituted D-glycopyranosyl units is considered here.

[3]Cotton print cloth was padded in a 20-percent aqueous solution of methyl vinyl sulfone to a 100-percent wet pickup and then in a 10-percent solution of NaOH saturated with sodium sulfate to an additional 50-percent wet pickup. The fabric was immediately inserted into a polyethylene bag (for 1 hr. or 24 hr.) or into a forced draft oven (5 min.).

REFERENCES

1. Charlesby, A., and Pinner, S. H. 1959. Proc. Roy, Soc. (London) A249 367.
2. Cirino, V. O., Bullock, A. L., and Rowland, S. P. 1968. Analyt. Chem. 40: 396-399.
3. ————————, Bullock, A. L., and Rowland, S. P. 1969. Jour. Polymer Sci. [In press]
4. Croon, I. 1958. Svensk Papperstid. 61: 919-921.
5. ————————, and Flamm, E. 1958. Svensk Papperstid. 61: 963-966.
6. ————————, and Lundberg, B. 1957. Svensk Papperstid. 60: 843-849.
7. ————————, and Purves, C. B. 1959. Svensk Papperstid. 62: 876-882.
8. Frick, J. G. Jr., Kottes, B. A., and Reid, J. D. 1959. Textile Res. Jour. 29: 314-322.
9. Guthrie, J. D. 1967. Textile Res. Jour. 37: 40-45.
10. ————————, and Heinzelman, D. L. 1969. Length of methylene bridges in cellulose formals estimated by O^{18} tagging. Pres. 157th ACS Natl. Meeting, April 13-18.
11. Haworth, S., Roberts, J. G., and Robinson, R. N. 1967. Textilveredlung 2: 361.
12. Hoiness, D. E., Wade, C. P., and Rowland, S. P. 1968. Canad. Jour. Chem. 46: 667-672.
13. Jeffries, R., Roberts, J. G., and Robinson, R. N. 1968. Textile Res. Jour. 38: 234-244.
14. Joarder, G. K., Brannan, M. A. F., Rowland, S. P., and Guthrie, J. D. 1969. Textile Res. Jour. 39: 49-54.
15. ————————, and Rowland, S. P. 1969. Textile Res. Jour. 39: 247.
16. Lanchenaner, A. 1969. Textile Res. Jour. [In press]
17. Martin, L. F., Bertoniere, N. R., Blouin, F. A., and others. 1969. Textile Res. Jour. [In press]

18. Patel, S., Rivlin, J., Samuelson, T., and others. 1968. Textile Res. 38: 226-234.
19. Ramnas, O., and Samuelson, O. 1968. Svensk Papperstid. 71: 674.
20. Roberts, E. J., and Rowland, S. P. 1967. Canad. Jour. Chem.45: 261-265.
21. ————————, and Rowland, S. P. 1969. Canad. Jour. Chem. [In press]
22. ————————, and Rowland, S. P. 1969. Textile Res. Jour. [In press]
23. ————————, and Rowland, S. P. 1969. Textile Res. Jour. [In press]
24. ————————, Wade, C. P., and Rowland, S. P. 1969. Textile Res.Jour. [In press]
25. Rollins, M. L., and Tripp, V. W. 1963. *In* Methods in carbohydrate Chem. III: 356, 364. New York.
26. Rowland, S. P., Bullock, A. L., Cirino, V. O., and Wade, C. P. 1968. Canad. Jour. Chem. 46: 451-457.
27. ————————, Cirino, V. O., and Bullock, A. L. 1966. Canad. Jour. Chem. 44: 1051-1058.
28. ————————, Cirino, V. O., and Bullock, A. L. 1969. Textile Chemist Colorist [In preparation]
29. ————————, and Post, A. W. 1966. Jour. Polymer Sci. 10: 1751-1761.
30. ————————, Roberts, E. J., Bullock, A. L., and others. 1969. Textile Res. Jour. [In press]
31. ————————, Roberts, E. J., and Stark, S. M. 1969. Textile Res. Jour. [In press]
32. Rowland, S. P., Roberts, E. J., and Wade, C. P. 1969. Textile Res. Jour. [In press]
33. Touzinsky, G. F. 1965. Jour. Org. Chem. 30: 426-428.
34. Warwicker, J. D., Jeffries, R., Colbran, R. L., and Robinson, R. N. 1966. Shirley Inst. Pamphlet No. 93. England.
35. ————————, and Wright, A. C. 1967. Jour. Appl. Polymer Sci. 11: 659-671.
36. Willard, J. J., Turner, R., and Tesoro, G. C. 1969. Textile Res. Jour. [In press]

NEW APPLICATION OF YARN MERCERIZATION IN COTTON FABRIC FINISH

[SUMMARY]

by

C. M. Welch, A. L. Murphy, and M. F. Margavio
Southern Utilization Research and Development Division
New Orleans, La.
(Presented by C. M. Welch)

The mercerization of cotton changes the crystal structure of the cellulose, and modifies the internal physical structure of the fibers. When accompanied by suitable tensioning procedures, it imparts increased luster and strength, in addition to enhanced dye affinity. Although usually carried out on fabric, mercerization is in many ways more effective if performed on yarn. In a fabric structure there is little room or freedom for movement of individual yarns and, consequently, little response is obtained to the swelling, shrinking, or stretching processes of tension mercerization. A fabric woven of tension—mercerized yarn is found to be more lustrous than fabric woven of untreated yarn mercerized in fabric form.

An important effect of tension mercerization is that it decreases the strength losses in cotton fabric caused by commercial wrinkleproofing treatments. The improvements are much greater if yarn mercerization is used than if fabric mercerization is used. In these laboratories it has been shown that in the wash-wear treatment of fabric, strength losses of 30 to 50 percent can be reduced to less than 5 percent by the use of yarn mercerization. By "wash-wear" is meant a level of wrinkle resistance corresponding to a Monsanto crease angle of 275° (W + F).

The method has also been tested at a very high level of crease-proofing—the "durable-press" level of 300° crease angles. At this level, strength losses of 50 to 66 percent are commonly encountered in the commercial processing of unmercerized cotton fabric. In the present studies, 60/2 combed Acala 4-42 gray yarn was slack-mercerized in 22-percent sodium hydroxide, causing 15-percent shrinkage. The yarn skeins were restretched to varying lengths while in the alkali, and were washed, neutralized, and dried without tension at the selected length. Samples of 112 x 60 broadcloth were woven from these yarns and also from the unmercerized yarn. The experimental and control fabrics were scoured in 2-percent sodium hydroxide, and boiled in anionic detergent—sodium pyrophosphate, by conventional procedures.

Durable-press treatment of these fabrics was carried out by procedures used commercially. The creaseproofing agent was 20-percent Permafresh 183 together with a polyolefin softener and the usual zinc nitrate catalyst. After drying and steam pressing, the fabrics were cured at 160° C. per 10 min. An afterwash with nonionic detergent was used.

In the case of yarn slack mercerized and restretched to the original length, the resulting durable press fabric had 2.02 times the breaking strength and 2.49 times the tearing strength of durable press fabric not yarn-mercerized. Wrinkle-recovery angles of test and control fabric were 303° and 301° (W + F). Durable-press appearance ratings of 5.0 were obtained. As compared with broadcloth woven of unmercerized yarn, and not given a durable press treatment, the experimental durable-press fabric showed only a 13-percent loss in breaking strength and also a 13-percent loss in tearing strength. The resin-treated control fabric showed 57-percent and 65-percent losses in breaking and tearing strength. Thus the effect of yarn mercerization was to cut strength losses to one-fourth or one-fifth their usual value.

Practically identical results were obtained on fabric woven of yarn-mercerized slack and restretched to 103 percent of original length. In the case of fabric woven of yarn mercerized at constant length, the improvement in strength retention was still rather large, though less than that for the above experiments. The loss in breaking strength was 23 percent and in tearing strength, 21 percent, calculated as above.

A study of yarn mercerization in knit fabric has also been started, and effects quite analogous to those

in woven fabrics have been discovered. Knit fabric made of 36/2 mercerized gray yarn was compared with the same construction of unmercerized yarn. The yarn mercerization, at 1.5-percent extension, was done commercially. The application of 20 to 24-percent Permafresh 183 led to wrinkle-resistant fabrics on which the yarn-mercerized knit possessed 1.75 to 2.00 times the bursting strength of the unmercerized knit. The application of 9 percent DMEU imparted a durable press appearance rating of 4.0 along with strength losses which were entirely negligible (0 to 3 percent) regardless of whether calculated from the strength of the unmercerized untreated control or the yarn-mercerized untreated control.

Other studies involve the application of chemically reactive dyes to yarn-mercerized fabrics. The whitening or "frosting" that occurs in vat-dyed fabrics after repeated laundering is preventable, if the dye can be covalently bonded to the cellulose throughout the cotton fiber. With certain of the reactive dyes, this uniform fixation is achieved in mercerized cotton.

NEW FLAME RETARDANT COTTON BATTING PRODUCTS

by
N. B. Knoepfler
Southern Utilization Research and Development Division
New Orleans, La.

For about a year and a half, we at the Southern Regional Research Laboratory have been involved in a research project in which the objective was the development of flame-retardant cotton batting products.

This research is a joint undertaking of the USDA, The National Cotton Batting Institute, The Textile Fibers and Byproducts Association, The National Cottonseed Products Association, and the Foundation for Cotton Research and Education. The research is also receiving indirect support from the National Association of Bedding Manufacturers.

The interest in the development of flame-retardant cotton batting products stems from the passage by the Congress of the Amendments to the Flammable Textiles Act of 1953, and the passage of the Highway Safety Act during the first session of the 90th Congress in late 1967.

As you know, more than 90 percent of the cotton batting products that are manufactured in the United States each year end up in such items as automobile seats, furniture, and mattresses. All of these items are covered specifically by the new laws.

What do these laws propose? This terminology is used since it will be some time before the Department of Commerce, who administers the Flammable Textiles Act, and the Department of Transportation, who administers the Highway Safety Act, can reasonably arrive at what might constitute acceptable flame retardance for home furnishings, including mattresses and furniture, and in automobile interiors.

All that can be said at this writing is that the products must demonstrate better resistance to burning than they do at present.

You will note that the research commenced before the laws were enacted. This was in anticipation that the laws would be passed and implemented in the forseeable future.

Our research to develop new flame retardant cotton batting products has taken two distinct paths.

Research over the past few years at this Laboratory has resulted in the development of a process wherein highly resilient, dimensionally stable cotton batting products having enhanced tensile strength, cohesion, resistance to compaction in use, and a high degree of integrity could be made. It is called the Cotton Flote process and it accounts for the use of about 70 million lbs. of certain types of cotton fibers per year.

This process essentially consists of the spraying of the cotton fibers with a treating formulation containing about equal parts of thermoplastic and thermosetting resins along with appropriate buffers and catalysts. You can see from the flow diagram that to produce Cotton Flote a bank of spray nozzles must be installed on the traveling apron of the garnett, and that an oven to dry and cure the product must be provided.

The types of cotton fibers that are used in Cotton Flote are first cut linters and various grades of textile wastes from gins and spinning mills. These fibers are generally blended in the ratio of 60 percent first-cut linters and 40 percent of the textile wastes. These are mechanically processed through a garnett, which is a coarse type of card, to form a web of fibers that have been opened and to some extent parallelized. The web is then sprayed with the treating formulation. The spray formulation usually contains about 20 percent by weight of the chemicals and 80-percent water. The delivery of treating formulation to the web is regulated so that the weight of the treating formulation equals the weight of the cotton fibers to be treated.

Typical formulations used to spray the web in the production of Cotton Flote are:

The thermosetting resins that are used in the Cotton Flote process are similar to those used in wash-wear and durable-press cotton fabrics. These resins are used to improve the inherent resilience of the cotton fibers. The thermoplastic resins that are used also confer some resilience to the product, but their main function is to bond the fibers to each other at points of contact. Their presence gives the product dimensional stability, enhanced tensile strength, and integrity.

By varying the ratio of thermosetting to thermoplastic resin, the resilience tensile strength, dimensional stability, and integrity can be varied to suit the end use. In addition, the density of the product can

Typical treating formulations
20-percent resin solids

Methylated methylol melamine	50 percent	Urea formaldehyde (modified)	50 percent
Vinyl acetate	50 percent	Vinyl acrylate	50 percent
Buffer or formaldehyde acceptor		Buffer or formaldehyde acceptor	
Catalyst (Magnesium chloride)		Catalyst (magnesium chloride)	
Water		Water	
Methylol imidazolidone	50 percent	Methylated methylol melamine	50 percent
Vinyl acetate—acrylate	50 percent	Vinyl chloride—acetate	35 percent
Catalyst (zinc chloride)		Styrene butadiene	15 percent
Water		Buffer or formaldehyde acceptor	
		Catalyst (magnesium chloride)	
		Water	

be controlled by changing the spacing between the conveyors in the drying/curing oven, with products having densities from 1.5 to more than 6 lb. per cubic foot possible with most commercial installations (fig. 4).

When we evaluate the performance of 2.0 lb. cu. ft. density Cotton Flote under compressional stress using a loading of 1.0 lb. per sq. in. of sample area, we find that the product recovers nearly 95 percent of its original thickness in 4 minutes. Conventional cotton batting of equal density only recovers 70 percent of its original thickness in the same time interval.

From this figure it can be seen that the Cotton Flote sample has a tensile strength of 20 lb. in the machine direction and 12.5 lb. in the transverse direction compared with 2.5 lb. in the machine direction and 1.0 lb. in the transverse direction.

What these numbers really describe is the tendency of the Cotton Flote to plump up and fill the automobile seat covering the mattress ticking or upholstry fabric fully to give a nice smooth appearance, and for the material to be strong enough that it is not damaged in the handling necessary during the construction of the mattress, upholstered furniture, or automobile seat.

To make the Cotton Flote products flame retardant, it is only necessary to modify the treating formulation to contain a suitable chemical that will reduce the flammability of the cotton fibers.

There are, of course, some "musts" and some "must nots" that enter into the picture. These are as follows:

Essential criteria for flame retardance treatments for Cotton Flote

The treatment must be:

1. Inexpensive.
2. Applicable from water system.
3. Effective on native linters and textile wastes.
4. Compatible with currently used chemical systems.
5. Durable to mild leaching, high humidity and temperature.
6. Effective at low levels of chemical add-on.
7. Odor free after drying and curing.
8. Effective in reducing after glow.
9. Physiologically inactive.

The essential criteria for flame-retardance treatments for Cotton Flote are low cost, because the finished product must sell for between 20 and 40 cents per pound. The treatment should, if possible, be applied from a water system to avoid any additional fire hazards in the batting plant. In addition, since the chemicals for the Cotton Flote system are applied from a water-based system, it would be

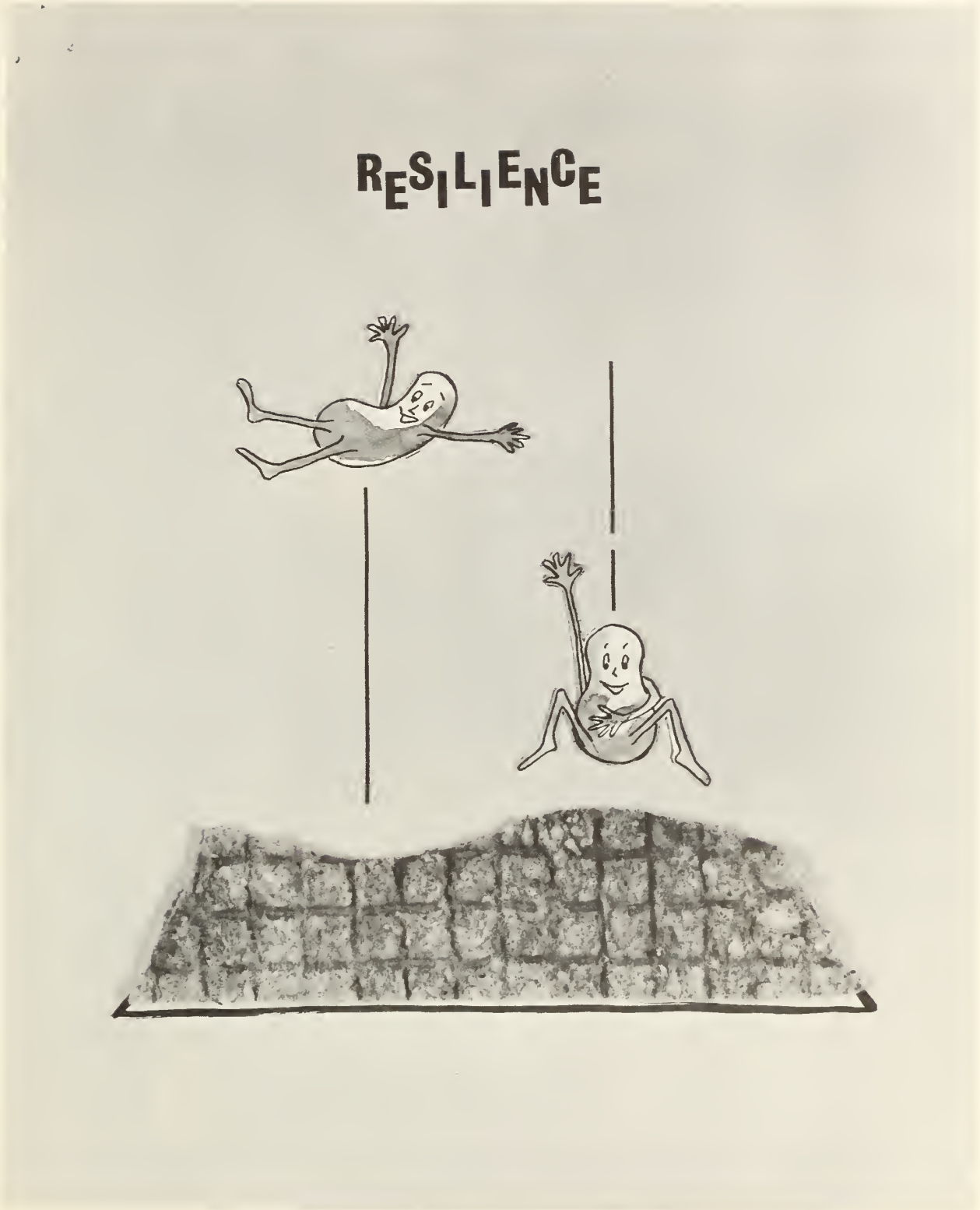


Figure 1.—High resilience.

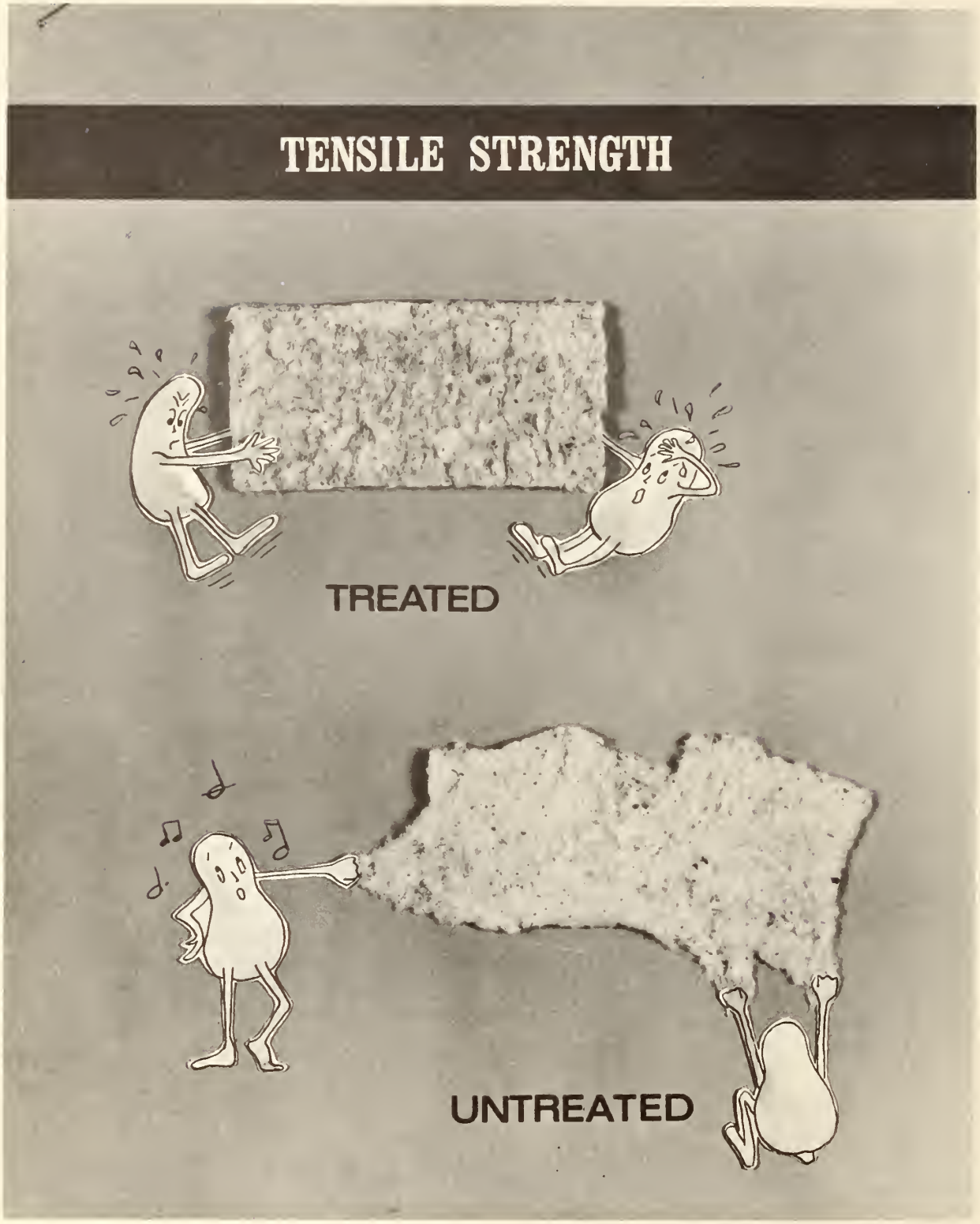


Figure 2.—Tensile strength.

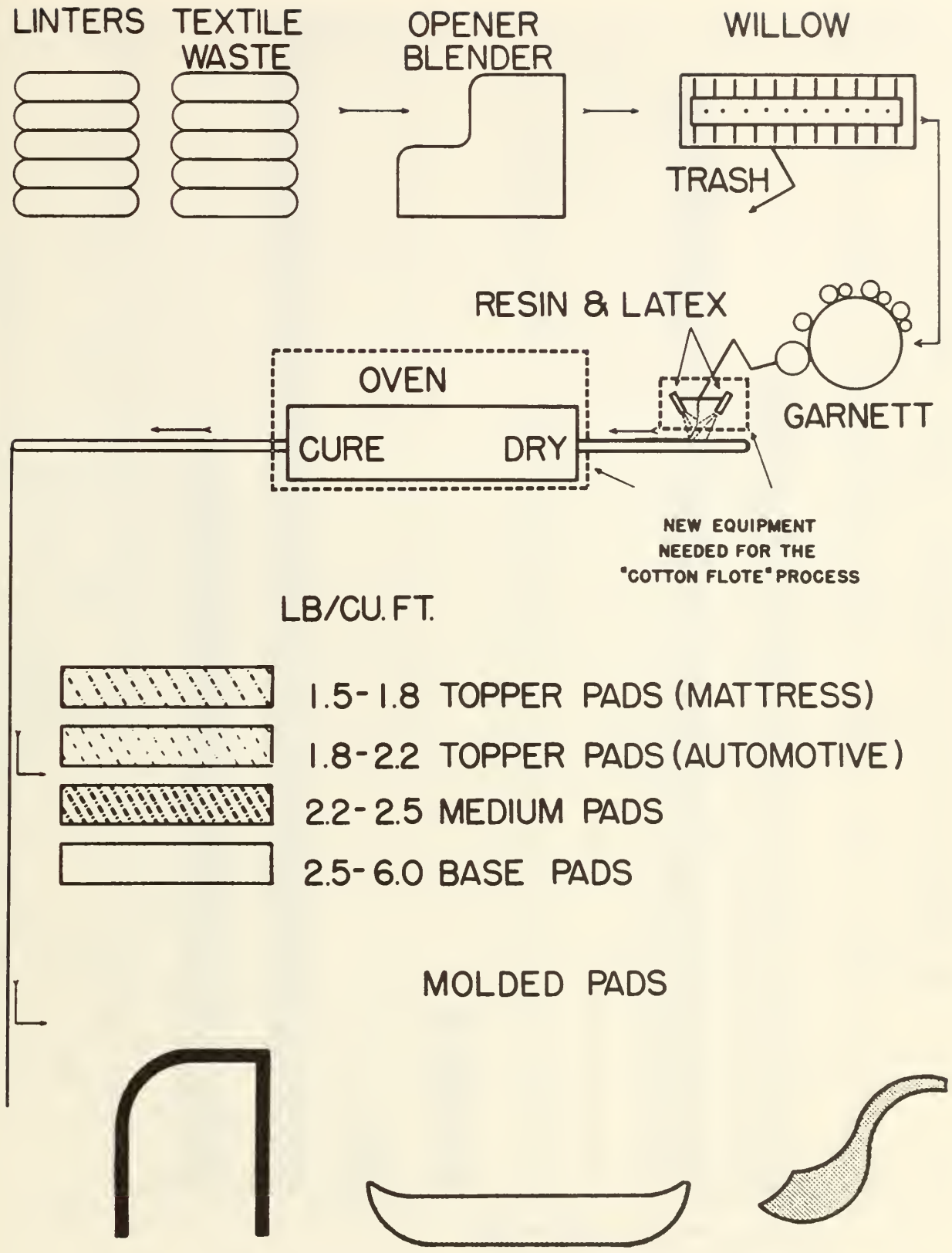


Figure 3.—Cotton Flote process.

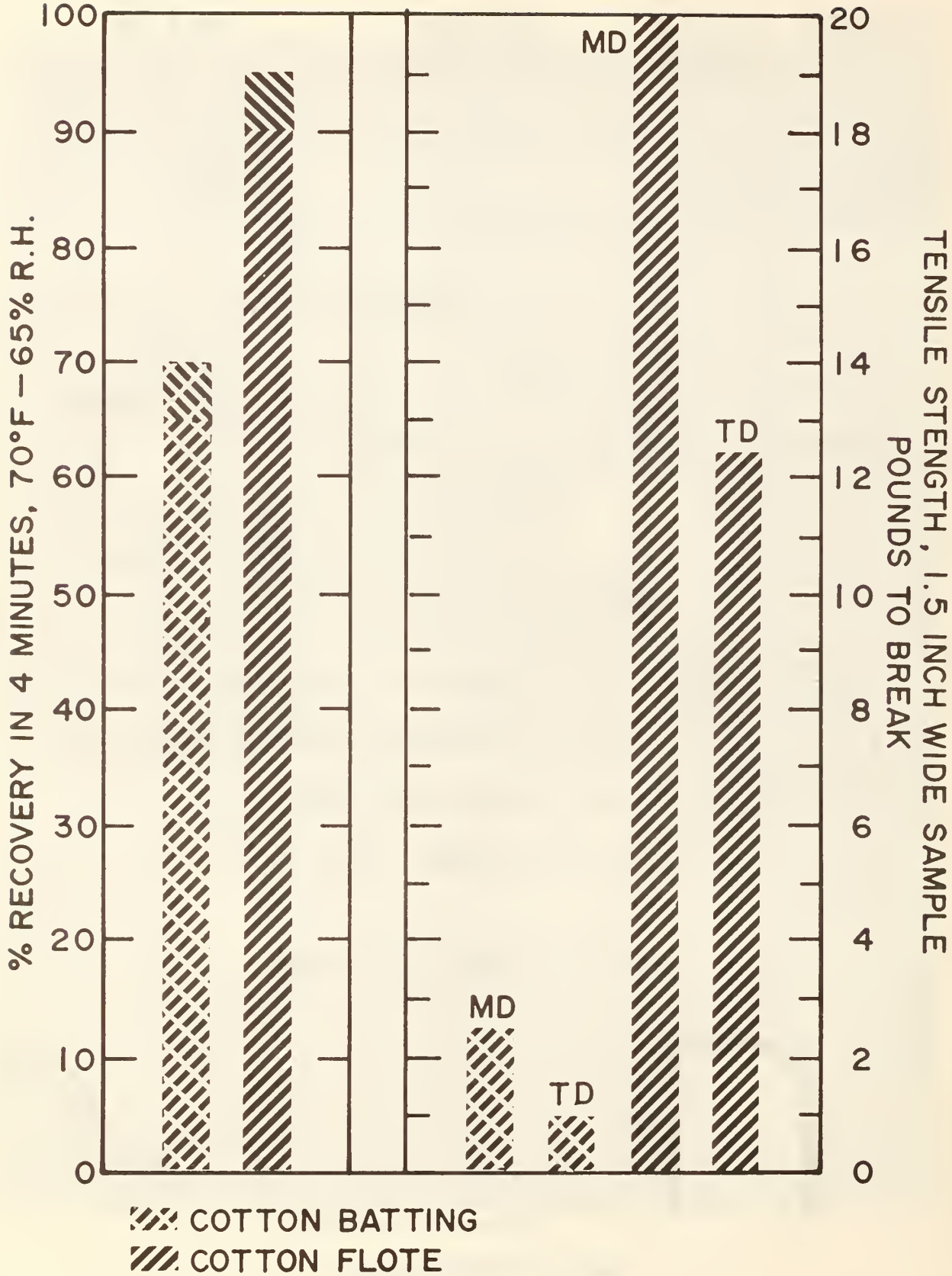


Figure 4.—Density control.

highly desirable to apply the entire treatment including flame retardant at one time. The treatment should be effective on the fibers as they are received and processed in a batting plant to avoid the necessity for scouring to remove unwanted waxes, pectins, and other extraneous foreign matter that usually accompanies cotton fibers of the type used in batting. Because cotton batting products are used under constantly varying environmental conditions, the treatment should resist removal of high humidty and high temperature, and should be durable to mild leaching such as might occur from perspiration, spillage of liquids, and the like. To keep the cost as low as possible, the amount of flame retardant needed should be as small as possible. Since many of the chemicals that confer flame retardance can possibly form undesirable odors under certain conditions, care needs to be exercised to select the chemical to avoid odoriferous problem.

Some chemical systems, such as borax, are quite effective in reducing flaming. However, cotton products treated with borax usually exhibit an afterglow that persists for a long time. This is undesirable because the glow temperature is generally several hundred degrees hotter than the flame. The final item means that we want to be sure that the chemicals do not affect the health of either the personnel manufacturing the item, or the eventual owner of the product by causing allergies or by being carcinogenic.

We have a few of the "must nots" that the treatment has to meet. They are:

Essential criteria for flame retardance

treatments for Cotton Flote

The treatment must not:

1. Be deliquescent
2. Affect the resilience or tensile strength of products.
3. Affect the moisture absorption-desorption of fibers.
4. Affect the air permeability of the array.
5. Dust or powder off the fibers.

First of all we do not want the treatment to absorb water from the air, we do not want it to adversely affect the resilience or the tensile strength of the products. Likewise, we do not want the treatment to interfere with the moisture absorption-desorption characteristics of cotton fibers, because this is indeed one of cotton's comfort factors. Because cotton batting functions like a bellows in pulling air in during expansion and expelling air upon compression, we do not want the treatment to intefere with the air permeability of the array.

Because we believe that for our research products we should select the most demanding test procedures, we chose to evaluate the products using a modification of the American Association of Textile Chemists and Colorists procedure 34-1964. This test involves hanging a sample 2 inches wide by 10 inches long vertically over a bunsen burner (fig. 5).

The flame burns for 12 seconds. We measure the time that the flame persists after the bunsen burner is extinguished, and the time that the red afterglow persists. We also measure the length of the main charred spot at the bottom of the sample and the overall char length including scorch from flashing. By these measurements we are able to differentiate between the effectiveness of a number of treatments to the point where we can, with reasonable confidence, select samples having different degrees of flame retardance. Since there is also the question as to flame retardance under a number of environmental conditions, we usually test the samples after (1) conditioning at 70° F. and 65 percent R.H. for 24 hours, (2) 100° and 100 percent R.H. for three days, (3) 158° for 16 hours, (4) after soaking with water and drying at 158° for 16 hours. At a later date we also plan to go back and test samples that have been stored in our pilot plant from 6 months to 1 year after manufacture to ascertain if the flame retardance is being retained.

Chemical systems.—A number of well known chemical systems improve the ability of cotton textiles to withstand flaming while undergoing oxidative decomposition. Among these are APO (tris [1-aziridinyl] phosphine oxide), THPC (tetrakis [hydroxymethyl] phosphonium chloride), and BPP (tris [2-3 dibromopropyl] phosphate). Unfortunately, these compounds sell for about $1.00 per pound and chemical add-ons depending on the density of the products of 10 to 20 percent are needed for cotton batting.

For economic reasons we had to seek effective flame retardants that would cost no more than 40 cents per pound. These compounds had to be effective at add-ons of less than 10 percent by weight. The inorganic borates, ammonium phosphates, urea phosphates, phosphorous containing derivatives of dicyandiamide, and borated amido polyphosphates were considered.

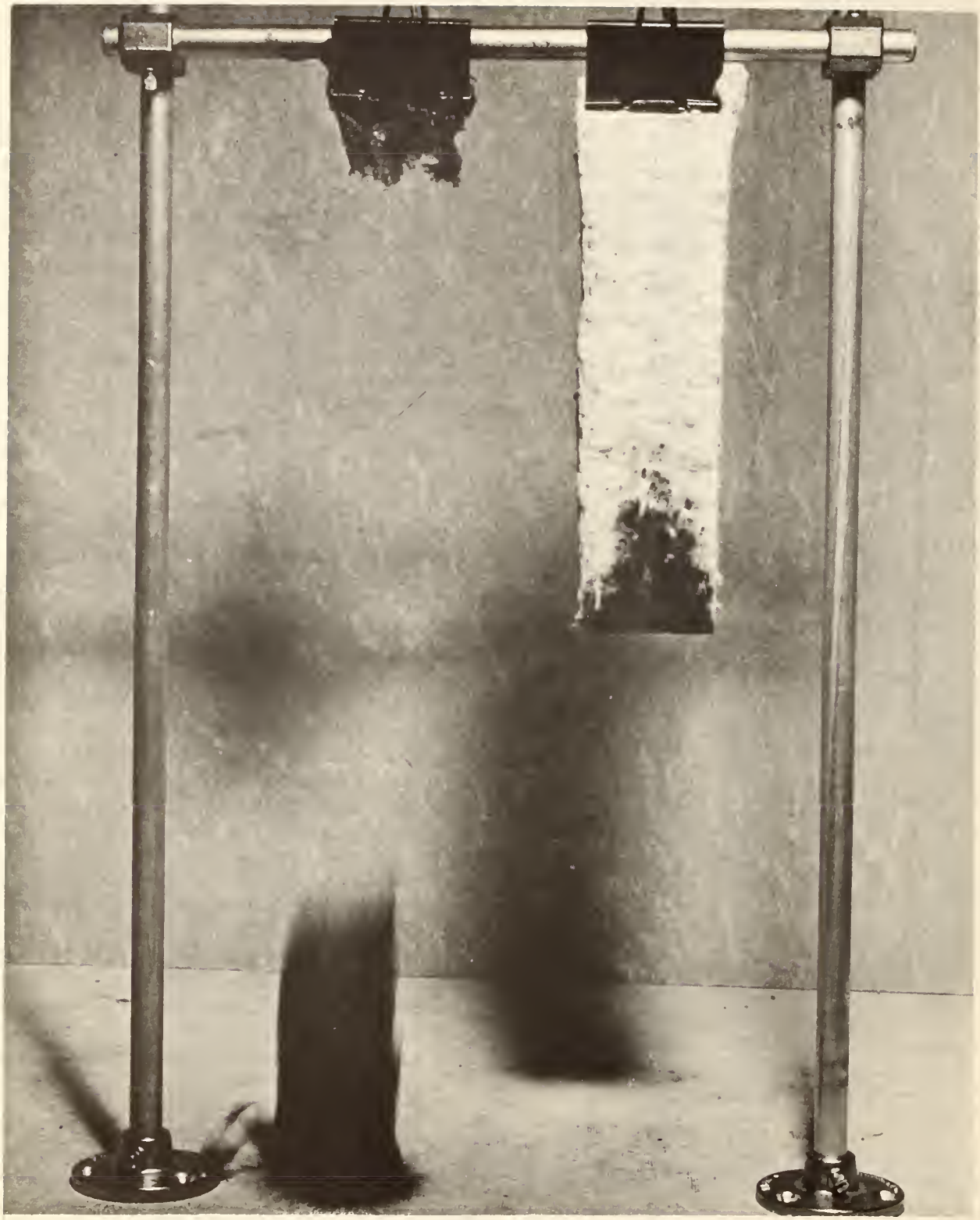


Figure 5.—Mock-up of apparatus for measuring flame resistance of cotton batting.

A number of these had to be more or less eliminated from further consideration for one or more reasons. For example, because of their solubility in water, the inorganic borates and the inorganic ammonium phosphate salts tend to be lost from the system under conditions of high relative humidity and where the sample had been subjected to soaking with water. In addition most of the borate salts give products that exhibit a tendency to glow after the source of ignition is removed.

The urea phosphates, the borated amido-polyphosphates, and the phosphorous derivatives of dicyandiamide gave promising results as outlined below.

Chemical composition and resilience characteristics:

Sample No.	A	B	C	Control
Thermosetting resin	MMM	MMM	MMM	MMM
Percent add-on	37.5	37.5	40.0	50.0
Thermoplastic resin	CL-ACRY	ACRY	ACRY	ACRY
Percent add-on	37.5	37.5	40.0	50.0
Flame retardant	BAP	DCP	UP	-
Percent add-on	25.0	25.0	20.0	-
Density lb./cu./ft.	2.0	2.0	2.0	2.0
Cyclic loading recovery[1]				
65 percent R.H.	95.3	94.3	92.2	93.7
100 percent R.H.	73.0	75.5	75.8	71.6

[1] After 4 minutes.

These are some typical formulations that we found to impart an acceptable degree of flame retardance. You will note from the percentages that we used for the better products the ratio of thermoplastic resin to thermosetting resin remains essentially equal to one. MMM stands for methylated methylol melamine, the CL-ACRY represents a vinyl chloride acrylate copolymer, the ACRY an acrylate polymer. For sample A, the flame retardant used was borated amido polyphosphate which has been coded BAP. For sample B, the DCP represents the phosphorous derivative of dicyandiamide, and for sample C the flame retardant designated UP was a urea phosphate complex. For these chemicals, the price range is from 20 to 30 cents per pound.

The last two lines show that the addition of the flame retardant to the Cotton Flote formulations did not adversely affect the resilience of the products when compared to the control shown in the last column.

Outlined below are the flame resistance characteristics of the products.

When the samples were conditioned at 70° F. and 65 percent relative humidity and then tested for flame retardance samples A, B, and C had no afterflame; that is, the products were self-extinguishing immediately upon removal of the external flame source. The control Cotton Flote took 3 seconds to self-extinguish the flame and it continued to glow for 21 seconds. If we compared these samples with a sample of conventional untreated cotton batting, we would find that the conventional batting would burn its entire length.

Flame retardance characteristics:

Sample No.	A	B	C	Control
70° F—65 percent R.H.:				
After flame (sec.)	0	0	0	3
After glow (sec.)	0	0	0	21
Overall char (cm.)	2	8	5	12
Main char (cm.)	1	5	4	8
100° F—100 percent R.H. (3 days):				
After flame (sec.)	0	0	0	9
After glow (sec.)	0	0	3	46
Overall char (cm.)	2	6	3	13
Main char (cm.)	1	4	1	8

The overall char and main lengths were well below the level of 15.25 cm. that we have more or less arbitrarily set as the limit. The control sample without the flame retardant, however, had considerably greater char length than did samples A, B, and C.

When we look at the performance of the samples after they had been exposed to 100 percent relative humidity at 100° F. for 3 days, we find that this rather tough set of conditions did not change the flame retardance performance of samples A and B. Sample C and the control did show significant change. In the case of sample C, it would still be acceptable, however, the 3-second afterglow observed would make the sample somewhat suspect over an extender period of use. The 5-second afterflame, the arbitrary maximum we allow, and the 46 second afterglow, where we also have established a 5-second maximum permissible, would cause the sample to be rejected. The overall char is also approaching the maximum permissible, as shown below

This shows the performance of the samples after they have been soaked with water to the maximum that they will hold, then the samples are dried at 158° F., and tested for flame retardance. Here again samples A and B were essentially unaffected by this procedure but sample C and the control, affected. The performance of the control appears to have actually improved by the soaking and drying. This is probably due to a better distribution of the chemicals in the batting. Under this test procedure, sample C

Flame retardance characteristics:

Sample No.	A	B	C	Control
158° F—16 hr. (dry):				
After flame (sec.)	0	0	0	2
After glow (sec.)	0	0	0	5
Overall char (cm.)	2	15	6	16
Main char (cm.)	1	8	2	6
158° F.—16 hr. (wet):				
After flame (sec.)	0	0	2	5
After glow (sec.)	0	0	5	3
Overall char (cm.)	2	8	5	11
Main char (cm.)	1	5	3	9

shows some afterflame, although it would be acceptable under our permissible limits.

Exposing the samples to 158° F. for 16 hours did not significantly change the performance of samples A and C in comparison with the test results shown previously but did affect the performance of sample B and the control. Note that for sample B the overall char length is approaching the maximum permissible, and for the control it has exceeded this limit.

By making minor chemical modifications in the flame retardants used for samples A, B, and C, we have been able to improve the performance of samples of Cotton Flote made with them so that they are acceptable under all test conditions.

One company is already marketing flame retardant mattresses and box springs based upon these research findings.

Flame retardant conventional cotton batting.—In another phase of our research, we are at present directing our attention to means of imparting flame retardance characteristics to conventional cotton batting which accounts for the use of about 750 million pounds of various grades of cotton fibers per year. A new cooperative research project, having the same sponsors as the work that led to the development of the Cotton Flote process, was initiated in April 1968.

The requirements for the application of flame retardant characteristics to conventional cotton batting are considerably different than those that apply to the Cotton Flote system, although many of the same chemical compounds can be expected to do the job effectively. For example, in the Cotton Flote process the bonding of fibers together at points of contact is a desirable characteristic that assists in maintaining the tensile strength, dimensional stability, and integrity of the products. In addition, the presence of the thermoplastic resin that serves as the bonding agent makes the removal of the flame-retardant chemicals more difficult at high relative humidity and even mild leaching. Furthermore, all of the needed chemicals are applied in an operation already incorporated into the process, and the fibers are in an open array and readily accessible to the treating formulation.

For conventional cotton batting there seems to be no real good place to apply the flame retardant chemicals to the fibers during normal mechanical processing. For this reason, flame-retardance treatments must of necessity be applied as a pretreatment before any mechanical processing of the fibers is undertaken.

The treatment for rawstock must meet essentially the same criteria that was listed for the Cotton Flote process. That is, it must be inexpensive, easy to apply, effective on native linters and waste, effective at low levels of add-on, durable to mild leaching and high temperature. It must be odor free in the finished product, effective in reducing afterglow, and physiologically inactive.

Here we see what the treatment should avoid, and these requirements are where the treatment for rawstock differs significantly from the requirements for Cotton Flote. The chemical used should not pick up water from the atmosphere and cause the fibers to become soggy and thus lose resilience. The treatment should not (1) change the physical characteristics of the fibers to the point where an inferior quality garnetted web is the result; (2 embrittle the fibers or bond them together to the point where large amounts of fibers are broken during garnetting; (3) affect the ability of the fibers to absorb and desorb moisture; (4) "deaden" the fibers to the point where they pack down and thus reduce the air permeability of the array; and (5) dust or powder off during mechanical processing, or be lost because of migration, dissolution, sublimation, dusting-off or other means during the useful life of the finished article. Many of these criteria eliminate from consideration old standby flame-retardance treatments such as borax, boric acid, ammonium salts, and other inorganic salts.

There are, of course, a number of ways that chemical systems could be applied to the fibers to achieve adequate impregnation of the flame retardant. Among these are spray flooding followed by dewatering by squeeze rolls or centrifugation, pressure impregnation such as is used in rawstock dyeing, and immersion followed by appropriate dewatering. We have only evaluated the last alternative in any depth.

The laboratory technique we devised consists of preparing a blend of fibers (60 percent first-cut linters and 40 percent various grades of textile wastes) in the form of a picker lap. This is a rather dense array of fibers that have been air-deposited on a screen in a random pattern. To facilitate handling, we wrap the picker lap in gauze because it has no tensile strength or integrity.

As a general rule, the samples for experimental use weigh between one-third and one-half pound.

The sample of gauze encased picker lap was then immersed in about 3 to 4 pounds of a treating formulation that contained a calculated amount of the flame retarding chemical designed to give the preselected add-on after drying, and curing where necessary. The usual wet pickup was 100 percent by weight of the cotton being treated, with control being obtained by passing the wet picker lap through adjustable squeeze rolls. Using this technique, we found that it is essential that the drying temperature be controlled to avoid migration of the treating formulation from the interior to the surface of the picker lap.

After processing, all of the samples were air-equilibrated for at least 24 hours before being garnetted and tested for flame retardance.

The flame retardance characteristics of four typical samples of cotton batting that had been pretreated to make the fibers flame retardant are given below.

Flame retardance characteristics:

Sample No.	D	E	F	G
70° F.—65 percent R.H.:				
After flame (sec.)	0	0	0	0
After glow (sec.)	0	0	0	0
Overall char (cm.)	2	6	4	7
Main char (cm.)	1	2	2	2
100° F.—100 percent R.H. (3 days):				
After flame (sec.)	0	0	0	0
After glow (sec.)	1	0	0	0
Overall char (cm.)	1	6	3	8
Main char (cm.)	1	2	2	2

Sample D contained 7.5 percent by weight of a borated amido polyphosphate. Sample E contained 8.1 percent by weight of a phosphorous derivative of dicyandiamide. Sample F contained 10.1 percent by weight of a propyl ammonium phosphate. Sample G contained 5.3 percent of a urea phosphate complex.

When these samples were tested for flame retardance after conditioning for 24 hours at 70° F. and 65 percent relative humidity and 3 days at 100° F. and 100 percent relative humidity, they showed excellent ability to resist burning. They all self-extinguish immediately upon the removal of the external source of flame. All samples except Sample D had no measurable afterglow. In the case of Sample D the afterglow was only 1 second. All of these samples had overall char lengths much below the 15.25 cm. that we have arbitrarily selected as the maximum permissible. The difference between the figures that are given for main char length and for overall char length are an index of the flash characteristic of the product. All of the samples shown performed well in this comparison.

The sample marked control—actually a sample of untreated cotton batting—burned its entire length under both sets of test conditions, that is, 70° F. and 65 percent relative humidity, and 100° F. at 100 percent relative humidity.

The results obtained when the samples were tested from flame retardance after being soaked with water and dried at 158° F. and after being exposed to 158° F. for 16 hours without being wet out are shown below.

Flame retardance characteristics:

Sample No.	D	E	F	G
158° F.—16 hr. (dry):				
After flame (sec.)	0	0	0	0
After glow (sec.)	2	0	0	0
Overall char (cm.)	1	6	2	8
Main char (cm.)	1	2	2	2
158° F.—16 hr. (wet):				
After flame (sec.)	0	0	0	0
After glow (sec.)	1	0	0	0
Overall char (cm.)	3	4	5	4
Main char (cm.)	1	2	2	3

In these tests all samples showed no afterflame at either test condition. Only sample D showed any afterglow, and this was 2 seconds in the dry 158° storage, and 1 second when dried at 158° F after being soaked with water. All samples had minimal overall char lengths, both overall and main char.

Based upon these test results all samples preimpregnated with flame retardents as shown would be acceptably flame retardant for cushioning applications.

The sample of conventional cotton batting burned its entire length after being wet out and dried at 158° F. and after being exposed to 158° F. dry for 16 hours.

Summary and conclusions: A number of low-cost chemical systems will confer a significant degree of flame retardance both to Cotton Flote and conventional cotton batting products.

The cost of the chemicals falls between 20 and 30 cents per pound, and chemical add-ons of between 5 and 10 percent by weight of the cotton treated appears to be adquate.

The chemical treatments that have been evaluated in this paper seem to meet the criteria of permanency, resistance to removal by elevated temperature, mild leaching, and high relative humidity when measured by the conditions set forth in GM test procedure 30 to 27 (1967).

The chemicals used are easily applied from water systems and have no history of acting as a causative agent for physiological changes in humans.

These chemicals are not easily removed by mechanical processing in the case of conventional cotton batting, and they do not significantly increase the fly generated during mechanical processing.

Based upon the performance data generated in this research, there seems to be every reason to believe that cotton batting products that demonstrate an acceptable degree of flame retardance can be produced economically on a commercial scale.

In the case of Cotton Flote this has already been done.

DISCUSSION

QUESTION: Why didn't you use the 45° angle test, and decrease the length of time of contact, rather than the vertical test? Most of the applications that you referred to are horizontal types of applications such as mattresses. In the case of a car, the chances of a lit cigarette or a burning match falling on the flat part of the seat are much greater than the vertical part of the seat, unless the car is immersed in gasoline and then the whole thing is burning and then success becomes moot.

MR. KNOEPFLER: Well, it is really a very difficult thing to decide what kind of test to use. We could not easily differentiate between samples by using a 45° test, so we elected to use a verticle test which is considered more severe.

Let me put it this way—the Society of Automotive Engineers, for example, have two tests that they are considering quite extensively for use in measuring the flame retardancy of seat cushion materials. They are using both the verticle and the horizontal. So, it is a question of trying to decide who you are going to satisfy and what might be a reasonable way of measuring flame retardancy or flammability.

QUESTION: What are the competing materials that might take the place of cotton, or are there competing materials at the present time?

MR. KOEPFLER: Oh, yes, the competition is tough. Polyurethane foam, for example, is quite extensively used in automobile cushions. Foam rubber is also used to a limited extent.

QUESTION: Is it necessary to treat those materials to protect them, or are they inherently flame retardant?

MR. KNOEPFLER: They have the same inherent problems of flammability as cotton does.

QUESTION: Then this is not a discriminatory thing toward cotton?

MR. KNOEPFLER: Oh, no. In fact, let me put it to you this way—the ammendments to the flammable textiles act may be the best thing that has happened to the cotton batting industry. We think that we can make cotton batting products flame retardant for less cost than foam manufacturers can make polyurethane foam flame retardant. Polyurethane foam, of course, is our biggest competition right now and increasing the price differential makes the use of cotton batting more attractive.

QUESTION: How about the toxicity of tne combustion problem? The reason I raise that question is because rubber and urethane combustion products are terrible.

MR. KNOEPFLER: That is right.

QUESTION: I'm just wondering if the byproducts from the flame retardant cotton batting are less hazardous?

MR. KNOEPFLER: We have discussed this with the people in the Department of Commerce, who will eventually be responsible for setting the standards to implement the flammable textiles act. They recognize that byproducts of combustion are a problem. What they are doing right now is trying to figure out how they can measure concentration and toxicity. For example, if you take a mattress in a room that is completely isolated, with all the doors and windows closed, and set it on fire, then you have one set of conditions. If you have a window and a door open with a 10-mile an hour breeze blowing through the room, you have something else.

It is very difficult to establish realistic test conditions. Until the Department of Commerce, in the case of furniture and mattresses, and the Department of Transportation, for Automobiles, set standards that we can attempt to meet, it is going to be difficult to decide what would or would not be acceptable.

HOW ARE FIBER BLENDS AFFECTING COTTON'S MARKETS?

by

H. G. Kennamer, Jr., and T. L. W. Bailey, Jr.
Institute of Textile Technology
Charlottesville, Va.

(Presented by H. G. Kennamer, Jr.)

In a presentation of this type it is first desirable to explain certain terms that are to be used in reference to the many types of textile fibers available. It is also desirable to define the term "Blend." For reasons of simplification, the term "Man-Made" will be used to describe any fibers that are not produced by natural processes, including man-made regenerated cellulosic fibers and the synthetic noncellulosic fibers. The term "Blend" will be used to describe any combination of two or more different fibers, regardless of the process used to combine them. The reason for such broad terminology in the definition of fibers and blends is that not only are many types of combinations of multifiber blends affecting the cotton fiber market, but are influencing all textile fiber markets.

In a discussion of textile fibers it is no longer practical to consider the position of only one fiber; rather, the relative position of all fibers must be considered. As specialized needs and requirement of fibers have developed, so have the fibers developed. Even the producers of natural fibers have recognized these needs and taken the steps within their capabilities to meet them. Fibers that could not, or did not meet these new requirements have always found themselves in the position of having to take a second or third row seat in the great textile drama.

Admittedly, we have to weigh the fact that some manmade fibers have filled needs that natural fibers could not have filled in the first place. The fact may have been, however, that had the manmade fibers not been available, or made available when the need arose, the need would have been modified to accommodate the natural fibers. The fact is, however, that the manmade fibers either were or did become available to fill these specialized needs.

Textiles, being one of the three essentials of life, food, shelter and clothing, is to this day one of the most dynamic of industries. It was the most dynamic in the days of the industrial revolution in that it was the first of all industrial manufacturing processes to recognize the need and potential of automation, and the first to utilize this method of production. It was also one of the first industries to recognize the need of alternate and varied sources of supply, and to take steps to develop these sources. The development of synthesized sources of supply in the textile industry has far exceeded that of other industries, including the development of synthetic or substitute foods. In view of many recent achievements, such as men living in outer space and under the sea, this is saying a great deal. It must be remembered, however, that textiles played their fair share of the role in making these accomplishments possible, in the form of woven textiles, knitted textiles, nonwoven textiles, combinations of these, and what have you. At such points in technical development we can be concerned only with the utility and performance ability of a textile fiber, and not with political implications attached thereto. The textile industry learned long ago that legislated raw material prices and supply were an unsound basis upon which to build production investments for years, or even months, in advance.

This means that each textile fiber must recognize, and capture, the area in which it can give optimum performance. It appears that to the natural fiber producer this means one thing and to the manmade fiber producer the same thing—get all of the market. Such is not possible for each fiber will ultimately have to be satisfied with those needs which it can best fulfill.

If the statement of a few broad facts is not enough, then these facts must be examined in greater detail. The total textile mill consumption of fibers in the United States, and this presentation is limited to the United States consumption, has increased by about 41 percent during the past 10 years. This should present a gratifying picture for textile fibers; and although it has for some, it has offered little consolation for others.

To analyze what happened during those 10 years, it is necessary to first look at the total comsumption of fibers in that period (table 1). The data in this table present a rather comprehensive summary of the

Table 1.—Estimated consumption of fibers in the United States, 1959-1968.

Fibers	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
					Millions of pounds					
Natural fibers[1]:										
Cotton	4,334	4,190	4,082	4,203	4,009	4,255	4,452	4,621	4,415	4,150
Wool	435	411	412	395	412	355	387	370	313	345
Silk	8	7	7	6	6	5	4	4	3	5
Total	4,777	4,608	4,501	4,604	4,427	4,615	4,843	4,995	4,731	4,500
Cellulosic:										
Acetate yarn	230	228	249	282	305	364	366	387	420	431
Acetate staple	70	60	53	41	59	59	59	59	55	50
Rayon yarn	508	427	392	385	381	399	410	390	310	363
Rayon staple	530	431	500	550	695	690	712	750	710	842
Total	1,338	1,146	1,194	1,261	1,440	1,512	1,547	1,586	1,495	1,686
Non-cellulosic:										
Acrylic and modacrylic staple	124	118	127	158	209	281	355	346	395	512
Nylon yarn	327	348	419	507	574	688	782	880	910	1,111
Nylon staple	29	28	36	51	56	70	79	98	100	139
Polyester yarn	19	21	20	21	37	46	55	75	100	232
Polyester staple	58	67	74	115	150	181	281	395	540	755
Spandex	—	—	2	5	5	6	7	9	11	12
Textile glass	147	177	149	177	182	221	269	314	309	400
Olefin yarn	7	13	18	23	29	44	60	95	115	212
Olefin staple	—	—	—	—	—	—	12	32	33	73
Others—yarn	22	17	16	19	22	22	17	15	10	10
Total	733	789	861	1,076	1,264	1,559	1,917	2,259	2,523	3,456
Total manmade fibers	2,071	1,935	2,055	2,337	2,704	3,071	3,464	3,845	4,018	5,142
Total, all fibers	6,848	6,543	6,556	6,941	7,131	7,686	8,307	8,840	8,749	9,642

[1] Does not include jute, hemp, sisal, flax, etc.

consumption of all fibers except jute, flax, sisal etc. As can be seen by these data cotton is the unquestionable leader, and one that some say has held its "share" of the market. Such interpretation of the data presented is grossly misleading. Certainly, cotton may have done an acceptable job of holding its share of the market in terms of the total poundage consumed each year, but not so with reference to its share of the increase in consumption. The share of cotton in the latter has been nonexistent. In the face of the rising total consumption of fibers, as given in table 1 and illustrated in figure 1, every fiber must show a net gain in order to say that they have maintained their respective position. As can be seen in figure 2 cotton has failed to do this, reflecting a net change since 1959 of minus several hundred million pounds and having experienced many ups-and-downs in the process. The manmade cellulosic fibers have done little better. Although the latter show a net gain of several hundred million pounds, the increase in consumption has not been in proportion to the overall increase in fiber consumption as illustrated in figure 1. It can only be assumed, therefore, that the noncellulosic fibers accounted for the overall increase in consumption. That is exactly what happened. As can be seen in figure 2, the increase in the consumption of the noncellulosic fibers fairly well parallels that of the overall increase shown in figure 1.

In figure 2 all of the noncellulosic fibers listed in table 1 have been lumped together, and there is reason for this. There is no question that certain of the noncellulosics have had more impact on the markets of cotton than others have had; but they all had some impact. Admittedly, the most significant of these has been the spun polyester staples which have shown an increase in yearly consumption of approximately 700 million pounds, or 1,300 percent since 1959. This alone is far more than enough to account for the negative change in cotton's position during that period, without even considering the other noncellulosic fibers; or without even considering the filament polyester.

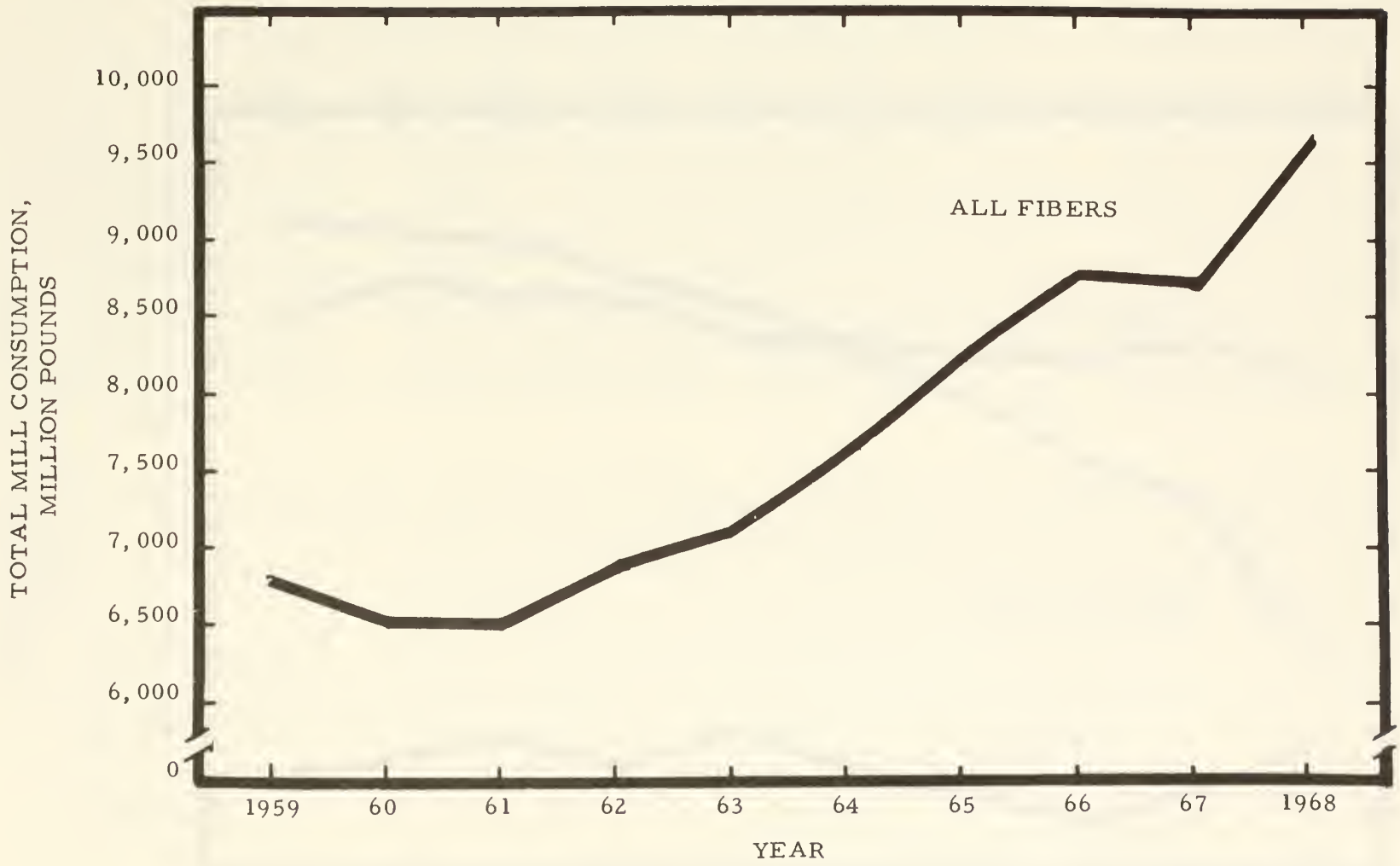


Figure 1.—Trend chart of total United States mill consumption of textile fibers, excluding bast type, 1959-1968.

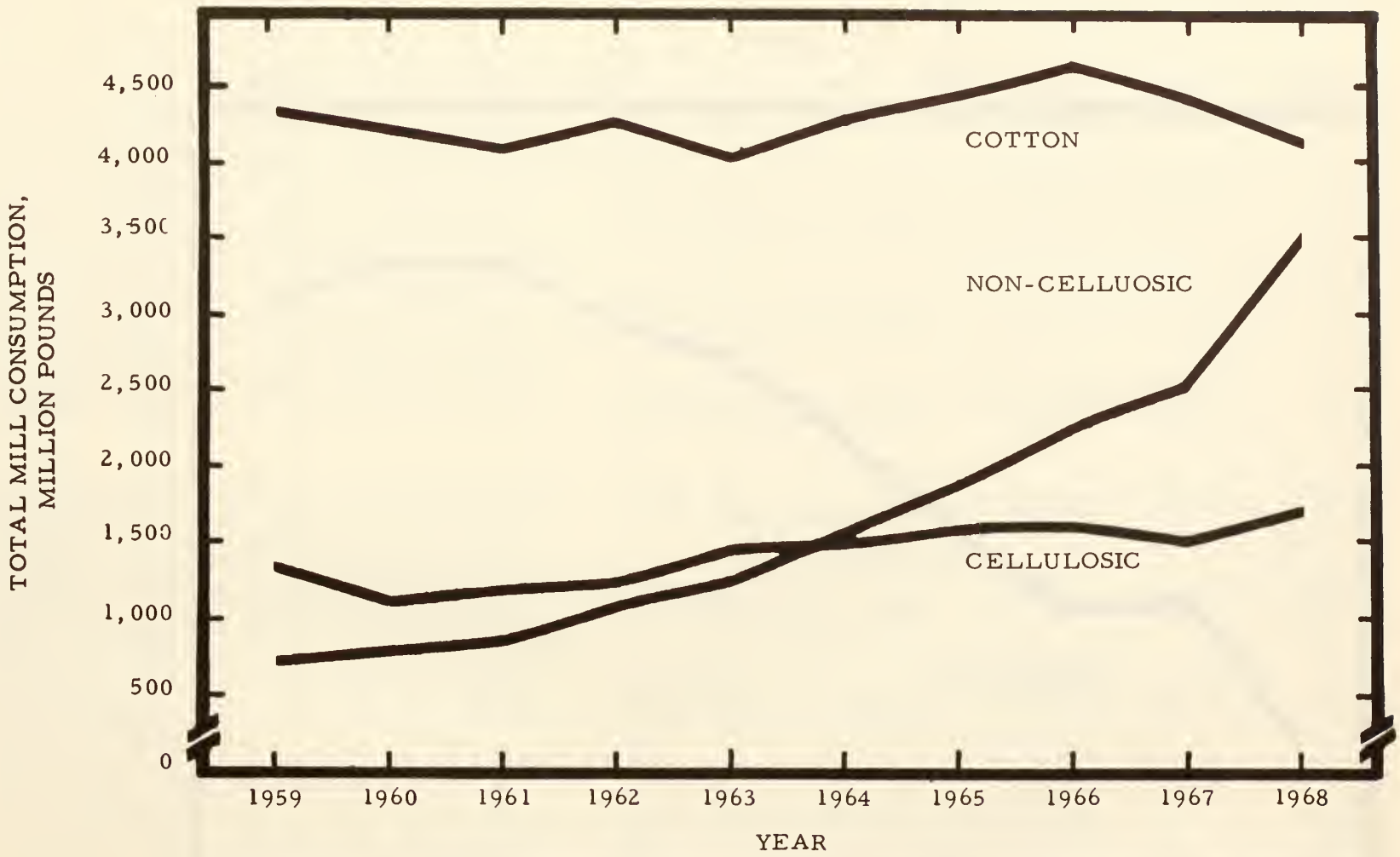


Figure 2.—Trend chart of distribution of United States mill consumption of cotton and manmade cellulosic and non-cellulosic fibers, 1959-1968.

As previously stated, the position of one fiber cannot be justly considered without considering the position of all others. To say that filament yarns have not affected cotton's markets is fallacy. During the past 10 years, at least until last year, cotton had suffered most in the apparel trade. It was necessary to look only at the change in the outer shells of men's, boys', girls', and women's jackets and other insulated clothing to see what happened during those 9 years. Twenty years ago these were largely made of cotton, by the early 1960's they were largely filament manmade yarns, or at least manmade/cotton blends.

The filament yarns have made many other inroads in former cotton markets. Polyester or nylon filament yarns or both are being used more and more in plyed yarns, with cotton or rayon or both for the production of industrial fabrics, such as heavy ducks and belting fabrics. In terms of poundage these are heavy consumers. Many rug and carpet backings once made of natural fibers are now made of 100 percent noncellulosic fibers; even the sand bag industry has felt the impact of the noncellulosics. The list seems endless, but this discussion should return to the matter of manmade/cotton blends, especially in the apparel and household trades.

Some years ago one of the largest merchandisers of fabrics in Great Britain said you could no longer determine the position of a man on the street by his clothing, as you had been able to do for centuries. This was not limited to Great Britain, rather it was true throughout most of the world. The silk shirt and the all-worsted or silk suit were marks of distinction, then came the blends. The blended fabrics first became known as the prestige fabrics and the fibers used to produce them were mistakenly identified as prestige fibers. All of these, according to many people, were to be short lived. As we now know, such was not the case.

Before the 10-year period being considered in this discussion rayon had, after several disappointing starts, established itself as a contender in the textile market. The great growth of rayons (cellulosics) during the 1952 to 1957 period was to be short lived because the noncellulosics were starting to make themselves felt by 1955. From that time forward a definite picture started developing that has led to the present position of cotton being replaced by polyester and polyester/cotton blends, and wool being replaced by polyester and polyester/wool blends as well as by acrylic and acrylic/wool blends. Rayon, which had long competed with cotton, and had made inroads as rayon/wool blends, found itself being replaced by polyester, even in the form of polyester/rayon blends. Nylon had made tremendous growth in both the filament and staple areas but found a rather difficult competitor in the form of polyester. The tire cord industry, for one of many, can attest to this.

Having reviewed some of the interesting background regarding fiber consumption, it is only fitting that the reasons for many of these changes be explored. The magnitude of these changes are clearly illustrated in table 2 and figure 3. These data clearly demonstrate that the percent of the market maintained by cotton during the past 10 years has shown a more or less steady decline from about 63 percent in 1959 to about 40 percent in 1968, and that the manmade cellulosics have experienced a decline of about 2 percent, both in the face of a rising total consumption. It only follows that this gap had to be filled, and was, by the noncellulosics. The latter showed an increase of from about 11 percent of the total consumption in 1959 to 36 percent in 1968, (fig. 3). It would appear, therefore, to be worthwhile to explore some of the reasons for this.

Again, certain facts must be faced. With present technology it is often possible to produce a better fabric, and to do so more efficiently, from a blend of fibers than it is from any of the components alone. For example, in the case of cotton and polyester, cotton meets certain comfort and appearance requirements that polyester alone cannot. On the other hand, polyester meets certain strength, easy care, appearance, and feel requirements that cotton alone cannot. The result is inevitable; a polyester/cotton blend. The surge in the acceptance of such fabrics by the U.S. consumer since 1963 has been almost unbelievable. The surge in acceptance during the past 18 months has been even more surprising.

One of the many examples of the latter can be found in household linens. During the 18 month period ending December 1968, the poundage of polyester consumed in bedsheets grew from virtually zero to about 20 percent of the fiber consumed in this household item. Some polyester producers feel that by the end of 1969 polyester will represent 40 percent of the fiber used in bed linens. According to some news media, one large textile company will have in operation in 1969 a new plant representing a 35 million dollar investment making mostly blended household linens.

It is often heard that the tremendous growth of

Table 2.—Percentage of total United States mill consumption of fibers filled by selected fibers, 1959-1968

Fibers	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
					Percent of total mill consumption					
Natural fibers[1]										
Cotton	63.3	64.0	62.3	60.5	56.2	55.4	53.6	52.3	50.5	43.0
Wool and silk	6.5	6.4	6.4	5.8	5.9	4.7	4.7	4.2	3.6	3.6
Total	69.8	70.4	68.6	66.3	62.1	60.0	58.3	56.5	54.1	46.7
Manmade fibers:										
Cellulosic	19.5	17.5	18.2	18.2	20.2	19.7	18.6	17.9	17.1	17.5
Non-cellulosic:										
Nylon	5.2	5.7	6.9	8.0	8.8	9.9	10.4	11.1	11.5	13.0
Polyester	1.1	1.3	1.4	2.0	2.6	3.0	4.0	5.3	7.3	10.2
Acrylic	1.8	1.8	1.9	2.3	2.9	3.7	4.3	3.9	4.5	5.3
Other	2.6	3.2	2.8	3.2	3.3	3.8	4.4	5.3	5.5	7.3
Total	10.7	12.1	13.1	15.5	17.7	20.3	23.1	25.6	28.8	35.8
Total, manmade	30.2	29.6	31.3	33.7	37.9	40.0	41.7	43.5	45.9	53.3

[1]Does not include jute, hemp, sisal, flax, etc.

the blends is the result of concentrated promotion on the part of the fiber producers with their many types of singular and joint advertising programs from spinneret to shirt. There is no doubt that this concentrated promotion has been a factor, and an important one. There are, however, many other reasons that must be recognized. It has already been pointed out that under certain conditions a better fabric can be produced from blends than from a single one of the components alone. A worthwhile example of these conditions is a fabric in which easy-care properties are desirable. Under these circumstances the use of polyester, or of some fiber with great chemical resistance and a heat memory, becomes of extreme importance. The U.S. public today demands more and more built-in services—in homes, in automobiles, in food, in household textiles, and in clothing. The U.S. consumer also is for the larger part in a position to pay for these built-in services.

The housewife of today can no longer spend all of her time cooking, washing, ironing, and cleaning house, because a very large percentage of them are today working to help earn the daily bread. Others refuse, and perhaps rightly so, to be chained to the house.

Table 3.—Average price of selected textile fibers, 1959-1968.

Fibers	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
					Cents per pound					
Cotton:										
Middling, 1-1/6-in.[1]	35.93	35.07	37.29	37.35	37.29	29.14	28.67	28.46	34.58	32.21
Adjusted [2]	43.02	42.00	44.65	44.70	44.65	34.89	34.33	34.08	41.41	38.57
Rayon:										
Regular, list	32	30	27	27	27	28	28	28	28	28
Modified, list	-	40	40	40	40	38	36	36	36	37
Polyester:										
List	136	129	117	114	114	99	84	81	63	61
Adjusted [2]	114.3	108.4	98.3	95.8	95.8	83.2	70.6	68.1	52.9	51.3
Acrylic:										
List	118	114	104	93	80	80	80	80	78	68

[1]Average of Southeastern, Memphis, Texas/Oklahoma, and California growths. Gross Weights, Landed Mill Group 201.

[2]Adjusted to allow for additional cover of polyester and net weight waste and cleaning costs. Polyester list price divided by 1.19. Cotton gross weight costs divided by 0.835.

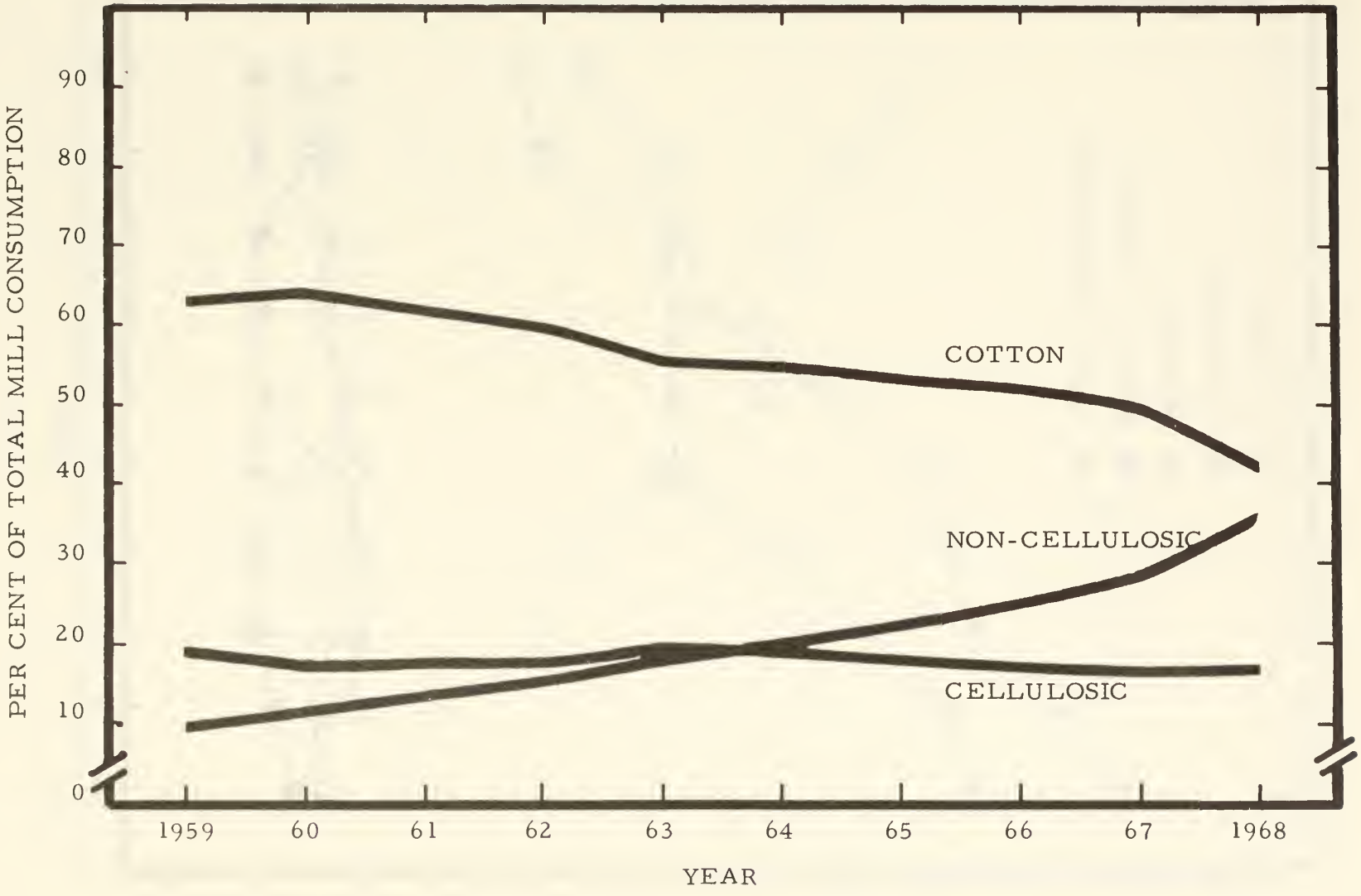


Figure 3.—Trend chart of distribution of United States mill consumption of cotton and man-made cellulosic and non-cellulosic fibers, 1959-1968.

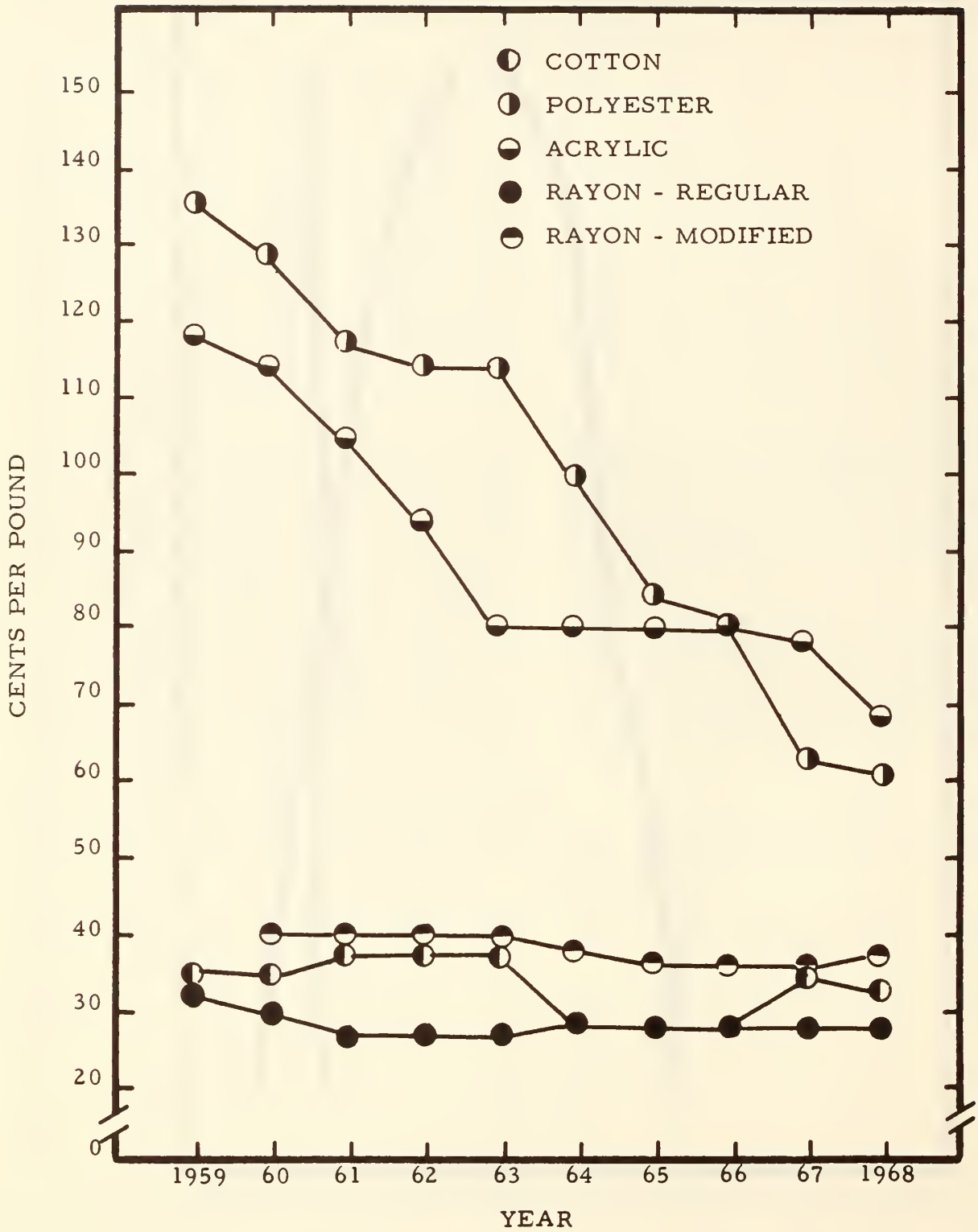


Figure 4.—Trend chart of United States average prices of cotton, gross weights landed mill group 201, and selected manmade fibers, list unadjusted, 1959-1968.

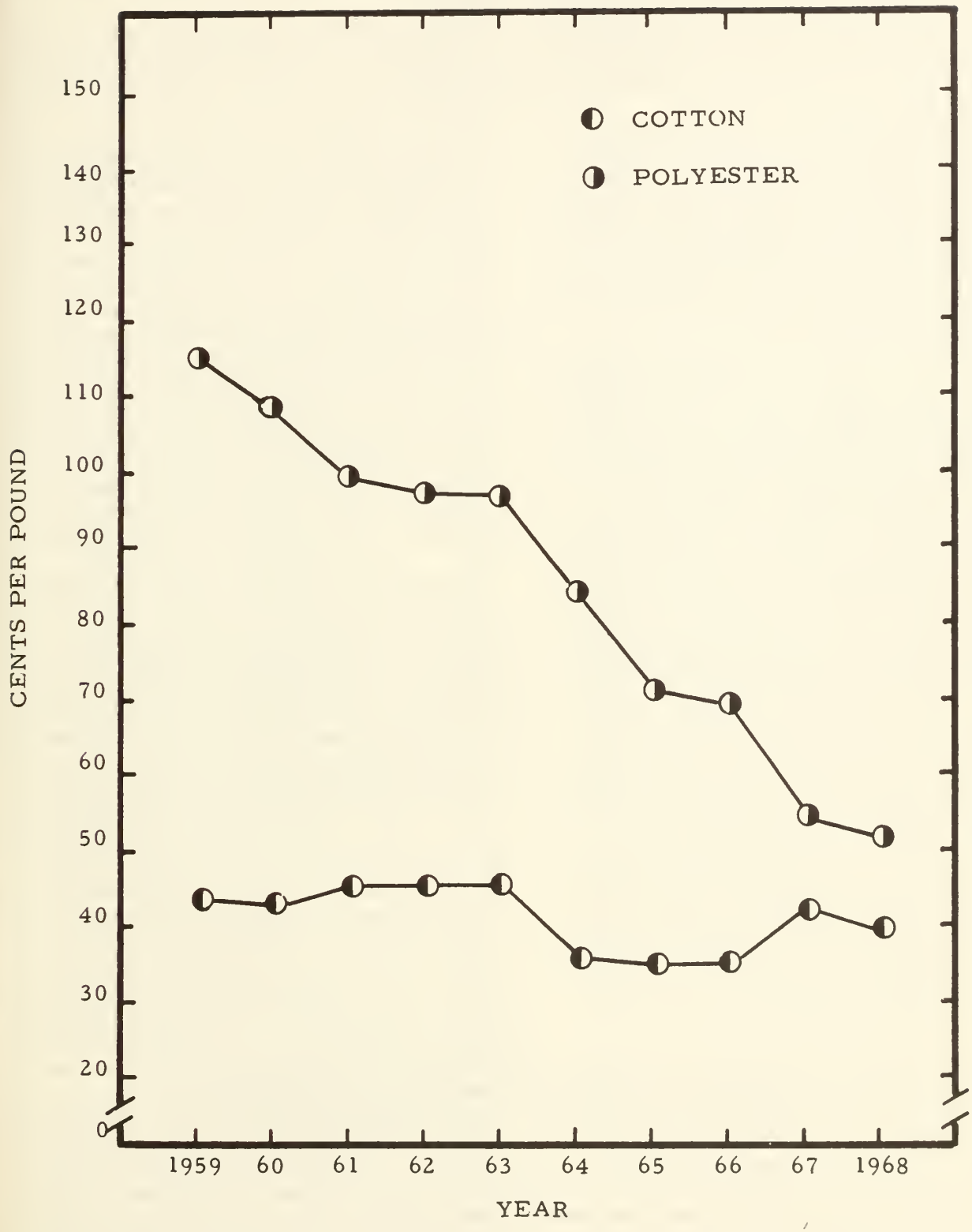


Figure 5.—Trend chart of United States average prices of cotton and polyester fibers, adjusted to cotton fiber equivalent, 1959-1968.

The consumer of today demands these built-in services, even though they realize that the product or garment may not last as long as the good old boiled and bleached 100 percent cotton product. This has been proved time and time again by the many thousands of families used as "guide panels" by the fiber producers.

Still another example is the boom in ladies' clothing made of knitted goods. With the advent of durable-press fabrics the matter of alterations became a serous problem. Unfortunately, all women are not built 36-24-36 at a height of about 5 feet 8 inches. Knits require less alteration, fit a more hetrogeneous group of shapes—male or female—and will probably be the next area into which the polyesters move in a big way.

Last, but certainly not least, there is now the matter of cost, which can be very misleading unless properly evaluated. During the days that polyester and acrylic held "prestige" positions, price seemed to be of little importance. The cleaned fiber cost of these fibers, as compared with those of cotton, were so far apart that the matter of competitive prices seemed to be of little consequence. Cotton certainly did not seem to be concerned about it, but perhaps unknowingly provided an excellent target. For many years rayon and cotton had been fighting a running price war, cotton being handicapped in this instance by legislation and short-term thinking. Suddenly, polyester started its rapid decline from a price of about $2.25 per pound in the early 1950's to its present position of a list price of $0.61 per pound. By 1959 polyester had dropped to $1.36 per pound, list price, with no great cry of alarm. Also, by this time the ratio of supply and demand came into the polyester picture. Meanwhile, rayon and cotton continued to battle prices. Polyester proceeded to dive boom them both, leveling off only at times when this seemed to be the thing to do, and then diving again as shown in table 3 and figure 4. Acrylic fiber is shown in figure 4 along with polyester to illustrate that polyester alone is not the only manmade noncellulosic to make these price moves.

To say what caused these declines in polyester price would be difficult, but only because it would be difficult to ascertain what influence each of several factors had. First, there has been increased production and competition in polyester, an increased number of producers, both domestic and foreign, and the United States does import foreign manmade fibers. There have been great strides in production efficiencies of manmade fibers. The recent limited production of cotton, fluctuating cotton prices, and the ever-present threat of changing cotton legislation, worked to the advantage of the manmade fiber producers.

It was said earlier that prices had to be properly evaluated before a valid comparison could be made. Because of its lower density, a pound of polyester will produce more fabric, insofar as cover is concerned, than will a pound of cotton. For this reason, the price of polyester must be adjusted downward for comparison with cotton as is done in figure 5. By the same token, a gross weight pound of Middling 1-1/16-inch cotton will produce only about 0.835 pounds of cleaned lint. For the latter reason, the true price of cotton must be adjusted upward for comparison. These adjustments almost present the true price picture in figure 5, but not quite. The polyester prices reflected here are list prices and a very sizable amount of polyester is available for less than list price. By adjusting the cost of polyester fiber down another 10 cents per pound, it can be realized that cotton and polyester are actually quite competitive. The true picture now starts to become quite apparent; easy care and stronger fabrics; better appearance, feel, and appeal; and rather competitive costs.

At this point the question of what will happen in the future arises. Polyester producers will continue to expand. In 1967 the noncellulosic producers announced planned expansion of production of 25 percent in this country; they expanded in the polyester field alone by about 40 percent. Some say they are planning an increase in 1969 of 32 percent. Based on past predictions as compared with performance, this may indicate an increase of about 50 percent. Already one new producer in the United States predicts an output of 80 million pounds in 1969. Still another factor is that polyester patents held by Imperial Chemical Industries, to whom many of the present producers of polyester pay royalty fees, are expiring. It can only be assumed that the future will result in more new producers of branded and unbranded polyesters; and probably some modifications in fibers. There probably will be stiffer inter-polyester price competition. It would appear that there probably will be more polyester/other-fiber blends, one of the latter of which will be cotton.

There is little doubt that by 1975, or earlier, there will be blend combinations that we are yet to learn about. One of these new fibers, Du Pont's Qiana, is already in sight and there are good possibilities that other producers are developing competitive fibers. The part that existing fibers play in the future depends upon what steps they take today to find and hold their place in the textile field.

ECONOMICS OF GROWING COTTON VS. OTHER CROPS

by

P. L. Strickland, Jr.

Economic Research Service
U. S. Department of Agriculture
Oklahoma State University
Stillwater, Okla.

The expanded research effort on cotton which was initiated in 1964 included efforts to reduce the cost of producing cotton and a special research effort to more effectively measure the actual cost of producing cotton. Research designed to meet both of these objectives has been underway for the past 5 years.

A previous speaker at this conference has discussed some of the research being conducted at the Delta Branch Experiment Station designed to develop production techniques that could reduce production costs of cotton. Some of these practices have proved effective and have been adopted. There are several research projects underway at this time to give economic evaluation to various systems of production in order to determine least cost production techniques. Some of the results from these research projects have been published.[1] [2]

An extensive nationwide survey of cotton producers was made to determine the cost of producing cotton. The first survey was completed in 1965 covering the 1964 cotton crop. Less extensive surveys have been conducted each spring since then to update and reevaluate the cost of production for the previous season. Fairly detailed analyses of the cost of producing cotton for the 1964, 1965, and 1966 seasons have been published.[3] [4] [5] These reports give us accurate data for analyzing the cost and returns from producing cotton.

The reports show that the total cost of producing cotton decreased 1.1 cents per pound (from 28.4 cents to 27.3 cents) for the United States from the 1964 season to the 1965 season. The direct cost per pound decreased 7 cents per pound (21.6 cents to 20.9 cents) from 1964 to 1965. A further decrease of 7 cents in total cost and 3 cents in direct costs were recorded for the 1966 season. Although these data indicate a decrease in the cost of producing cotton, they do not necessarily indicate that farmers have a greater incentive to increase cotton production. What is the competitive position of cotton compared with other crops that can be produced by the farmer? Is the profit a farmer can make from producing other crops approaching the profit from producing cotton?

Cotton vs. other crops.—A farmer making a decision about which crops to produce usually has one overriding criterion. "Which crop will make me the most money?" Several other factors may have entered into the total framework of the decision-making environment. The farmer is usually limited to the crops he knows how to produce. Facilities and equipment may limit consideration of some enterprises. Some crops have more risk and variability in income than the farmer is willing to accept. Thus, he cannot consider these crops. Other factors, such as allotments, may limit the amount of a crop the farmer can produce.

Within the limitations of his decision factors, the farmer becomes an economic man, concerned primarily with the amount of profit that he can make. He will make the choice of crops to grow strictly on the basis of which will return him the most money within his given resources.

Let me here dispel a couple of false impressions that I have heard in the past few years. The first one is the statement often heard that if production controls were removed, all cotton production would move to the Mississippi Delta and Western States

[1] Martin, Neil R., Jr., Nix, James E., McArthur, W. C., and Brannen, S. J. Effects of Alternative Production Practices on Costs and Returns in Producing Cotton in Selected Areas of Georgia. Univ. Georgia, College of Agriculture Experiment Stations, in cooperation with Farm Production Economics Division, Econ. Res. Serv., USDA. Res. Bull. 34, May, 1968.

[2] Robinson, Bobby H., and Butler, Charles P. Requirements for Costs of Producing Cotton and Competing Crops with Alternative Techniques, Upper Coastal Plains, South Carolina. Dept. Agr. Econ. Rural Sociol., South Carolina Agr. Expt. Sta., Clemson Univ., Clemson, South Carolina, Report AE312. April 1968.

[3] Starbird, I. R., and Hines, F. K. Cost of Producing Upland Cotton in the United States, 1964. Econ. Res. Serv., USDA, Agr. Econ. Report No. 99. September 1966.

[4] Starbird, I. R., and French, B. L. 1965 Supplement to Cost of Producing Upland Cotton in the United States, 1964. 1965 Sup., Agr. Econ. Report No. 99. September 1967.

[5] Starbird, I. R., and French, B. L., Cost of Producing Upland Cotton in the United States, 1966. A Preliminary Report, Econ. Res. Serv., USDA. January 1969.

because they can produce cotton cheaper than other areas. This is not necessarily true. A farmer in the Central Texas Blacklands isn't concerned about how cheap they produce cotton in the Delta when he makes his decision to grow cotton. His main concern is whether or not cotton will make him more money than grain sorghum. If it will, he will plant cotton and will continue to do so, with or without controls, until grain sorghum or some other crop will give him more profit. It is true that, if the price of cotton were to decline substantially, the low cost of production areas would be able to stay in production at a profit longer than higher cost of production areas.

The other false impression comes from strict evaluation of yields. Some people see the 2 to 3 bales per acre yields in the western irrigated areas and use this criterion alone to compare areas. The facts are that western irrigated producers are using some high-priced land and some high-priced irrigation water with high labor costs. Thus, their average cost per pound may not be any lower than some other producing areas. In fact, some areas in Texas have the reverse situation, very low yields per acre but also extremely low production costs. The latest report on cost of producing upland cotton shows the Black Prairie and Rolling Plains areas with about one-fourth the average per acre yield as southern California and southwestern Arizona, but all three areas have about the same average cost per pound of lint.[6] A much more important factor separating the areas is the quality of the cotton produced. Although the average cost per pound in the areas is about the same, the average price received is from 6 to 10 cents higher in the far western areas. These western producers also may have crop alternatives that compete closely with cotton. Therefore, the relative profitability of cotton may be less than in some areas where cotton produces a much lower yield.

How is cotton competing with other crops?—The costs of producing cotton reports contain very good data for evaluating cotton. They give average cost for the United States, average costs for the several regions specified, and a distribution of cost for these regions. By using the yield levels and various cotton prices, the profit from cotton can be calculated for the various regions. If such information were available for other crops, a year by year comparison of the profit from cotton and from other crops could be made. Unfortunately, comparable data for other crops are not available in such quantities. Thus, comparisons of the competitive position of cotton in relation to other crops within an area are infrequently made.

In the work associated with Aggregate Production Analysis System (APAS) Farm Production Economics Division of ERS, USDA, we develop cost and returns budgets for the major crops in most of the production regions in the United States. These data are then used to analyze the effect of various alternative programs or policies on the aggregate production of the various crops. To indicate how cotton is presently faring in comparison to competing crops, I have summarized some of the budget data for cotton and competing crops for several areas throughout the southern region (table 1). The data on cotton are not identical to the cost reported in the cost of producing cotton bulletins. In most cases, more than one budget was developed for such area so that several figures would have to be averaged to compare with the cost survey. Although the cotton cost data are comprehensive and accurate, we have no comparable data for other crops. These data used in our analysis were developed by the same source at the same time and should give better comparison than by comparing data developed by two sources at separate times.

The cost data used are the variable cost of production only. They do not include any change for land investment, equipment investment, or for general farm overhead expense. They do include a charge for all labor, both operator and hired, used in the production. The failure to include the fixed charges will make each enterprise appear more profitable than it actually is. However, since the same charges for land and general overhead would apply to either crop grown on the same acre of land, the relative profitability of the two enterprises would be affected only by the difference in machinery investment used on the various crops.

The net return to fixed factors per acre of land thus is a return to management, land, equipment, and general farm overhead. The return is per acre of land. The returns to 2 x 2 cotton which requires 2 acres of land must be divided to the 2 acres. The returns data are based strictly on the commodity price as stated. They do not reflect any price support, diversion payment, or other government program subsidy.

In the Mississippi Brown Loam and the Delta area, cotton is by far the most profitable crop. Soybeans are generally second, profitwise. Yet the difference in

[6] See Footnote 5.

net return to fixed factors per acre of land of cotton over soybeans ranges from $17 per acre on clay soils in the Delta to over $80 per acre on the best soils in the Brown Loam area. Another way to look at the difference is to determine the variation in cotton prices that could be tolerated before the returns per acre would be greater from producing soybeans. Assuming an original 24 cents per pound cotton price, the price could decrease by 2.8 cents on clay soils in the Delta and by 11.2 cents on 2 x 2 cotton on the best soils in the Brown Loam. At these price levels, the farmer would make exactly the same from cotton or soybeans.

In the Northeast Arkansas area, rice is the most profitable alternative to farmers, showing about $90 greater return to fixed factors than cotton. Cotton has about $20 greater net returns than soybeans. However, in this area and in other rice areas, the competition between cotton and rice is limited at present because they are both restricted by allotments and because the type of soil suited to each is a little different.

In the Texas and Oklahoma cotton areas, the major competition comes from grain sorghum and wheat. In the Texas Black Prairie, there is at present very little difference in net returns per acre from cotton or grain sorghum without considering government support payments which are available on both crops. Since these two crops are the only major alternatives available in the area, they are restricted more by acreage allotments than by farm resources. Farmers in the area continue to plant both to protect their allotments and to take full advantage of government programs.

Cotton is more profitable than wheat and grain sorghum in the Plains areas of Oklahoma and Texas. However, there is very little difference in profitability of irrigated cotton and irrigated grain sorghum in the High Plains area. The difference between cotton and wheat in the Low Plains area seems rather large. However, the wheat returns are relatively low when no certificate payments are included. Also, most farmers in this area utilize winter wheat pasture for grazing stockers and receive as much as $10 per acre for pasture rent. The value of this pasture has not been included.

In the southeast areas, cotton does not hold the competitive edge as in the southcentral. In the four major cotton producing areas, soybeans compete very favorably. In the Coastal Plains areas, there is only slightly more profit per acre of cotton than per acre of soybeans on the large farms and soybeans are more profitable on the small farms.

Peanuts were compared with cotton in the Geor-

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1]

Item	Unit	Mississippi Brown Loam					
		Cotton Class I soil		Soybeans (bu.)	Cotton Class II soil		Soybeans (bu.)
		Solid	2 x 2		Solid	2 x 2	
Yield/acre	lb./lint	800	1,224	25	675	971	25
Variable cost/acre	dollars	111.75	157.12	38.72	111.48	149.14	38.72
Less value of seed	do.	30.06	47.90	---	26.42	38.00	---
Net variable cost/acre	do.	81.69	109.22	---	85.06	111.14	---
Net variable cost/lb.	do.	.102	.089	---	.126	.114	---
Variable cost/unit	do.	---	---	1.55	---	---	1.55
Net return to fixed factors/acre.	do.	110.31	92.27	17.56	76.94	60.95	17.56
Cotton price/lb. lint	do.	.24	.24	---	.24	.24	---
Competing crop/unit	do.	---	---	2.25	---	---	2.25
Difference in net returns to fixed factors (cotton-competing crop).	do.	92.75	74.71	---	59.38	43.39	---
Cotton price at which indifference to competing crop.	do.	.124	118	---	.152	.150	---

See footnote at end of table.

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	Delta							
		Sand			Loam			Clay	
		Cotton solid	Cotton 2 x 2	Soybean (bu.)	Cotton solid	Cotton 2 x 2	Soybean (bu.)	Cotton solid	Soybean (bu.)
Yield/acre	lb./lint	790.	1209.	22.	710.	1022.	24.	610.	22.
Variable cost/acre	dollars	112.84	146.72	22.81	113.94	143.64	23.78	122.44	23.60
Less value of seed	do.	31.59	48.35	---	28.40	40.88	---	24.39	---
Net variable cost/acre	do.	81.25	98.37	---	85.54	102.76	---	98.05	---
Net variable cost/lb.	do.	.102	.081	---	.120	.101	---	.160	1.07
Variable cost/unit	do.	---	---	1.04	---	---	.99	---	---
Net return to fixed factors/acre.	do.	108.35	95.90	26.69	84.86	71.26	30.22	48.35	25.90
Cotton price/lb. lint	do.	.24	.24	---	.24	.24	---	.24	---
Competing crop/unit	do.	---	---	2.25	---	---	2.25	---	2.25
Difference in net returns to fixed factors (cotton-competing crop).	do.	81.66	69.21	---	54.64	41.04	---	22.45	---
Cotton price at which indifference to competing crop.	do.	.137	.126	---	.163	.160	---	.203	---

See footnote at end of table.

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	Northeast Arkansas			Texas Blacklands			
		Cotton		Rice (wt.)	Cotton Blackland	Grain sorghum (wt.)	Cotton Grayland	Grain sorghum (wt.)
		Clay	Loam					
Yield/acre	lb./lint	460.	590.	46.37	308.	24.86	238.	17.16
Variable cost/acre	dollars	128.31	116.12	101.82	59.17	28.86	57.37	28.09
Less value of seed	do.	19.15	24.58	---	11.16	---	8.57	---
Net variable cost/acre	do.	109.16	91.54	---	48.01	---	48.80	---
Net variable cost/lb.	do.	.237	.155	---	.156	---	.205	---
Variable cost/unit	do.	---	---	2.20	---	1.16	---	1.64
Net return to fixed factors/acre.	do.	1.24	50.06	134.66	13.59	14.64	−1.20	1.94
Cotton price/lb. lint	do.	.24	.24	---	.20	---	.20	---
Competing crop/unit	do.	---	---	5.10	---	1.75	---	1.75
Difference in net returns to fixed factors (cotton-competing crop).	do.	−133.42	−84.60	---	−1.05	---	−3.14	---
Cotton price at which indifference to competing crop.	do.	.530	.383	---	.203	---	.213	---

See footnote at end of table.

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	Oklahoma-Texas Low Plains					
		Loam		Sandy		Clay	
		Cotton	Wheat (bu.)	Cotton	Wheat (bu.)	Cotton	Wheat (bu.)
Yield/acre	lb./lint	315.	28.	325.	22.	200.	18.5
Variable cost/acre	dollars	41.22	18.71	43.92	21.08	36.72	18.94
Less value of seed	do.	11.81	---	12.15	---	7.52	---
Net variable cost/acre	do.	29.41	---	31.77	---	29.20	---
Net variable cost/lb.	do.	.093	---	.098	---	.146	---
Variable cost/unit	do.	---	.668	---	.958	---	1.02
Net return to fixed factors/acre.	do.	33.59	16.29	33.23	6.42	10.80	4.18
Cotton price/lb. lint	do.	.20	---	.20	---	.20	---
Competing crop/unit	do.	---	1.25	---	1.25	---	1.25
Difference in net returns to fixed factors (cotton-competing crop).	do.	17.30	---	26.81	---	6.62	---
Cotton price at which indifference to competing crop.	do.	.145	---	.118	---	.167	---

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	High Plains			
		Dryland solid		Pre + 2 Irrigated solid	
		Cotton	Grain sorghum (wt.)	Cotton	Grain sorghum (wt.)
Yield/acre	lb./lint	177.	10.67	570.	70.0
Variable cost/acre	dollars	24.52	8.87	71.44	56.33
Less value of seed	do.	6.37	---	20.52	---
Net variable cost/acre	do.	18.15	---	50.92	---
Net variable cost/lb.	do.	.103	---	.089	---
Variable cost/unit	do.	---	.83	---	.80
Net return to fixed factors/acre.	do.	17.25	9.80	83.08	66.17
Cotton price/lb. lint	do.	.20	---	.20	---
Competing crop/unit	do.	---	1.75	---	1.75
Difference in net returns to fixed factors (cotton-competing crop).	do.	7.45	---	3.09	---
Cotton price at which indifference to competing crop.	do.	.158	---	.205	---

See footnote at end of table.

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	Southeastern Coastal Plain			
		Small farm[2]		Large farm[3]	
		Cotton	Soybeans (bu.)	Cotton	Soybeans (bu.)
Yield/acre	lb./lint	422.	25.	509.	25.
Variable cost/acre	dollars	116.99	35.18	111.72	28.90
Less value of seed	do.	16.54	---	19.92	---
Net variable cost/acre	do.	100.45	---	91.80	---
Net variable cost/lb.	do.	.238	---	.180	---
Variable cost/unit	do.	---	1.41	---	1.16
Net return to fixed factors/acre.	do.	2.43	19.82	32.29	26.10
Cotton price/lb. lint	do.	.244	---	.244	---
Competing crop/unit	do.	---	2.20	---	2.20
Difference in net returns to fixed factors (cotton-competing crop).	do.	−17.39	---	6.19	---
Cotton price at which indifference to competing crop.	do.	.285	---	.232	---

See footnote at end of table.

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	Georgia - Alabama Coastal Plain					
		Small farm[2]			Large farm[3]		
		Cotton		Peanuts (lb.)	Cotton		Peanuts (lb.)
		Solid	2 x 2		Solid	2 x 2	
Yield/acre	lb./lint	435.	601.	1,824.	478.	658.	1,824.
Variable cost/acre	dollars	113.91	144.79	101.45	99.48	124.95	89.84
Less value of seed	do.	17.11	23.64	---	18.80	25.88	---
Net variable cost/acre	do.	96.80	121.15	---	80.68	99.07	---
Net variable cost/lb.	do.	.222	.201	---	.169	.150	---
Variable cost/unit	do.	---	---	.055	---	---	.049
Net return to fixed factors/acre.	do.	2.82	8.24	117.43	28.78	25.80	129.04
Cotton price/lb. lint	do.	.229	.229	---	.229	.229	---
Competing crop/unit	do.	----	---	.12	---	---	.12
Difference in net returns to fixed factors (cotton-competing crop).	do.	−114.61	−109.19	---	−100.26	−103.24	---
Cotton price at which indifference to competing crop.	do.	.492	.592	---	.439	.543	---

See footnote at end of table.

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	Alabama Limestone Valley					
		Small farm[2]			Large farm[3]		
		Cotton Solid	Cotton 2 x 2	Soybeans (bu.)	Cotton Solid	Cotton 2 x 2	Soybeans (bu.)
Yield/acre	lb./lint	487.	710.	30.1	586.	856.	30.1
Variable cost/acre	dollars	112.22	143.78	37.66	101.62	113.47	32.60
Less value of seed	do.	18.92	27.56	---	22.75	33.25	---
Net variable cost/acre	do.	93.30	116.22	---	78.87	80.22	---
Net variable cost/lb.	do.	.191	.164	---	.134	.103	---
Variable cost/unit	do.	---	---	1.25	---	---	1.08
Net return to fixed factors/acre.	do.	19.83	24.35	27.96	57.26	59.31	33.02
Cotton price/lb. lint	do.	.232	.232	---	.232	.232	---
Competing crop/unit	do.	---	---	2.18	---	---	2.18
Difference in net returns to fixed factors (cotton-competing crop).	do.	−8.13	−3.61	---	24.24	26.29	---
Cotton price at which indifference to competing crop.	do.	24.9	24.2	---	19.1	17.1	---

See footnote at end of table.

Table 1.—Comparisons of relative profitability of cotton and competing crop, selected areas in southern region of the United States [1] —continued

Item	Unit	Tennessee Brown Loam							
		Small farm[2]				Large farm[3]			
		Cotton Soil I	Soybean (bu.)	Cotton Soil II	Soybean (bu.)	Cotton Soil I	Soybean (bu.)	Cotton Soil II	Soybean (bu.)
Yield/acre	lb./lint	622.	30.	530.	23.	708.	30.	615.	23.
Variable cost/acre	dollars	134.19	37.84	124.54	35.78	109.69	27.06	99.80	25.70
Less value of seed	do.	25.38	---	21.62	---	28.88	---	25.08	---
Net variable cost/acre	do.	108.81	---	102.92	---	80.81	---	74.72	---
Net variable cost/lb.	do.	.175	---	.194	---	.114	---	.121	---
Variable cost/unit	do.	---	1.26	---	1.56	---	.90	---	1.12
Net return to fixed factors/acre.	do.	47.14	26.96	29.95	13.90	96.69	37.74	79.46	23.98
Cotton price/lb. lint	do.	.25	---	.25	---	.25	---	.25	---
Competing crop/unit	do.	---	2.16	---	2.16	---	2.16	---	2.16
Difference in net returns to fixed factors (cotton-competing crop).	do.	20.18	---	16.05	---	58.95	---	55.48	---
Cotton price at which indifference to competing crop.	do.	21.8	---	.220	---	1.67	---	.160	---

[1] Data obtained from unpublished sources are developed in the Production and Resource Response Group, Farm Production Economics Division, Economic Research Service, USDA.
[2] Small farms—Less than 100 acres of cropland, 2-row equipment.
[3] Large farms—100 acres and more of cropland, 4-row equipment.

gia-Alabama Coastal Plains. Profitwise, there is almost no comparison. Peanuts give about $100 per acre more profit than cotton. The cotton price would have to increase to 40 cents per pound or more before cotton would compare favorably with peanuts.

In the Alabama Limestone Valley and Tennessee Brown Loam areas, cotton shows a more favorable position over soybeans. The difference in per acre profits from cotton and soybeans on the large farms in these areas range from about $24 to about $85. These figures are in the same range as existed in the Delta area.

The comparisons in this discussion have dealt with the general competitive crops. In each area, there are no doubt one or more specialty crops which, when produced in limited quantities, will give as much or greater income than cotton. Such crops include a wide variety of vegetables, sunflower, and others. These crops, however, are usually considered to be limited in their use potential because of limited market availability, limited skills for production or because of usually unstable price conditions from year to year. Thus, to the individual farmer who could meet or accept some of these objections, they could offer good potential for competition for cotton. However, for the entire cotton industry, there should be little concern at present for the competition to cotton from these crops. Looking to the future, with canning companies offering contracts which provide more stable price conditions and as more farmers gain the managemant ability to produce vegetables, competition will increase. However, this competition will probably be more between these crops and soybeans or feedgrains than with cotton.

Summary

Continued production of cotton will depend largely on whether cotton will make the individual farmer more profit than other crops the farmer can grow. In most of the areas in the southern region, cotton is more profitable than other crops except for rice and peanuts. Since these crops are both produced under governmental control, there is little chance for expanding these crops at the expense of reduced cotton acreage.

In most areas from the Southeast through the Delta, soybeans are the closest competitor to cotton. With the tremendous increase in soybean production over the past few years, the price situation with soybeans is such that a decrease in price and profitability of this crop is very likely. Thus, cotton should continue to hold a competitive edge.

In the Texas-Oklahoma areas, cotton and grain sorghum or wheat are very closely competitive, profitwise. Therefore, the extent to which production of these crops changes will depend on what happens to the other crops. Changes in government programs or prices could change the competitive position. In general, farmers will probably continue to plant both crops and take full advantage of government support programs.

Competition from other specialty crops will continue to increase in most areas. However, the high variability of yields and prices of most of these crops will keep them from becoming major crops. Also, most of the increase in production of these crops will come at the expense of soybeans and other crops, not cotton.

DISCUSSION

MR. F. FORTESS; May I take the opportunity to perhaps make a contribution in the form of a discussion? Some very serious questions were raised here in terms of: What were the mistakes that the Cotton Processing Industry could have made in neglecting the potential threat of complete replacements, or at least partial replacements, in the form of blends? Although the picture that is presented here is an accurate one, there is one aspect that was not given the emphasis that it deserves and that is the creation of variants or modifications within the basic fiber families. All that was stated here listed acrylic as a fiber, polyester as a fiber, without taking into consideration that one of the real advantages available to the man-made fiber producer is that he does not have to make one standard product. You are restricted in cotton—you don't have very much flexibility in cotton in the sense that you would like to see a lot more Sea Island or very long staple, fine thickness cotton, but unlike the fiber producer you don't have the freedom to significantly alter cotton. The man-made fiber producers have the real advantage of being able to make very fine, very strong, high-shrinkage or low-shrinkage properties. You name it and they can modify the fiber and today blended with cotton there are at least five different type of polyester variants that have been developed for different end uses and for different types of properties, for mill efficiency, as well as for end-use

performance. I think that this is an aspect that must not be neglected when one considers the reasons for blending with cotton.

If any of you start thinking in terms of blended fiber programs, even if it is the so-called reverse blend of low percent of polyester, the objective must be to upgrade certain performance characteristics of Permanent Press garments. You will have to start thinking in terms of a careful selection of the variant types and not just think of polyester as a single fiber.

Now, there is one area in which cotton is being pushed out of, and where, perhaps, it doesn't have to be. We have just touched on it briefly and that is the high wet modulus rayon. The high wet modulus rayon is a different animal entirely to the old type of ersatz replacements for cotton. These fibers have been engineered and totally made to have the proper characteristics of strength and wet resistance and some of the improved properties for blending with polyester and with acrylic and some of the other fibers.

Now, one of the unjustifiable criticisms of cotton/polyester blends that is being overcome by blending with high wet modulus rayon is that the high wet modulus rayon in a blend with polyester can be made into a smooth, soft, and elegant slack fabric. It is inferred that cotton could not by proper selection of non-sized and dyeing processes be made into something that feels a little bit better than some of the stiff boards that are being produced in some of the cotton processing dye houses with the polyester/cotton blend. Unless the technologists are available to the textile industry to adapt cotton in certain blends to make a more elegant, better quality fabric, then you are going to be 100 percent pushed out of the casual slacks and the better quality slacks fabrics that are now being blended with 100 percent man-made fibers— the high wet modulus rayon and the various types of polyester. I think that with very little effort on the part of the cotton people they could win back certain areas that have been thrown out by emphasizing quality, upgrading performance, and upgrading elegance. We're still mostly thinking about how to do things cheaper and faster in the hopes that maybe that is how we can compete with the man-made fibers, and I say that that is not the way to increase its profitability.

R. J. MIRAVALLE: I think that one of the things you said about the variants in the man-made fibers is also true and always has been true in cotton, namely, that we are dealing with a blend of cottons of varying growths and varieties. In my limited experience seldom, if ever, is cotton of one growth and variety spun into yarns without blending it with cottons of other growths or varieties. One of the most difficult factors facing a cotton breeder interested in determining the spinnability of a newly bred cotton is to get this cotton spun in blends with other cottons. He almost always obtains spinning results on the new cotton spun by itself or 100 percent. This isn't the normal way cotton is spun. Cotton-cotton blends are the usual route. I noticed that in some of the talks yesterday and in some of the talks today that the fiber that was used was Acala 442. It is simply economically impossible to spin yarn made entirely of Acala 442. We do have blends of cotton and varieties to achieve these same things that were discussed. You do have cotton-cotton blends.

QUESTION: What types of work are going on in our Utilization Laboratories that would take into consideration cotton as just a part of the commodity going into the finished product rather than the total of it? We try to add characteristics to cotton by various procedures that are going on, but in our Utilization Laboratories are we studying blends as a possible way of using cotton, or are we keeping our heads under and saying that we have to go it alone?

J. J. MIKELL: Who would like to answer that question?

F. R. SENTI: You have raised a point that has been much discussed among ourselves and with the cotton industry. There is always the question of whether you are going to help the cotton or whether you are going to hurt cotton by doing research on blends. The problem is whether research would demonstrate that low level blends, that is, low levels of synthetics in the blends, give properties such that they displace high level blends and that the results would be to the benefit of cotton.

This result isn't easy to predict or to demonstrate.

QUESTION: Are we limited by legislation that would restrict to the natural fibers or not?

F. R. SENTI: No. We are not. Our objective of research is to get the maximum usage of cotton for the cotton farmers.

We have done some research on blends. We have investigated the soil release properties of all-cotton

fabrics and of blends with synthetics. This research has shown that all-cotton and low-level blends had advantages.

We have also done some work on blends in our research on the development of flame resistance treatments for cotton fabrics. We found that low-level blends had better properties than high-level blends, at least for certain synthetic fibers. At the outset one might have predicted that this finding would be the likely result and that the result would demonstrate an advantage for cotton or low-level blends.

The problem is to identify the particular fabrics end uses where one could through the proper kind of research demonstrate advantages for cotton or low-level blends. But a broad program on blends isn't simple to define and implement. We can't investigate all synthetic fibers at all levels in blends, but we have to focus on definite areas where we have a basis for expectation of advantage for cotton.

H. G. KENNAMER: I'd like to make a comment if I might. I would like to say that I think that the work done, for example, in the Department of Agriculture in cotton research through the years, has been admirable. I think that one of the greatest failings in the cotton industry, and I have had a little experience in this area, came in the merchandizing.

The fiber producer, when he comes to you to sell you the fiber, can tell you what it is and what it will do, and what you can do with it. But, I would venture to say that there are very few merchandisers of cotton today that can do that.

I have heard talk at many meetings of this type and at other research meetings regarding cotton about the fragmentation among the cotton producers, as compared with their competitors, the man-made producers. Fragmentation doesn't end with the producer, it goes all the way through the industry. I firmly believe that in the area of merchandising is where the greatest hope lies. This includes quality merchandising, techniques, and such rather than straight commodity merchandizing.

ATTENDANCE LIST

Bailey, T. L. W., Jr., Institute of Textile Technology, Charlottesville, Va. 22904

Bloodworth, Morris E., Dept. Soil and Crop Sciences, Texas A&M Univ., College Station, Tex. 77843

Brannan, Betty J., Agr. Ext. Serv., Inst. Food Agricultural Sciences, Univ. of Florida, Gainesville, Fla. 32601

Buck, George S., Jr., National Cotton Council of America, P. O. Box 12285, Memphis, Tenn. 38112

Chambers, Doyle, Agr. Expt. Sta., Louisiana State Univ., Drawer E, Univ. Station, Baton Rouge, La. 70803

Cheatham, R. J., 4619 Mandeville St., New Orleans, La. 70122

Cox, Carl, Jr., The Cotton Research Committee of Texas, 300 Cotton Exchange Bldg., 608 North St. Paul St., Dallas, Tex. 75201

Ewing, E. C., Sr., Delta and Pine Land Co., Scott, Miss. 38772

Ewing, Early C., Jr., Delta and Pine Land Co., Scott, Miss. 38772

Fortess, Fred, Consumer Technical Relations, Celanese Fibers Marketing Co., 522 Fifth Ave., New York, N. Y. 10036

Fynn, P. J., Merchandise Testing, J. C. Penney Company, Inc., 1301 Avenue of the Americas, New York, N. Y. 10019

Galbraith, Ruth Legg, Textiles and Clothing Div. Dept. Home Economics, Univ. of Ill., Urbana, Ill. 61801

Green, John M., McNair Seed Co., P. O. Box 706, Laurinburg, N. C. 28352

Hawkins, Louis E., Agr. Expt. Sta., Oklahoma State Univ., Stillwater, Okla. 74074

Heffner, Lawrence L., Cotton Chemical Finishing, 212 David Clark Labs., Fed. Ext. Serv., School of Textiles, North Carolina State Univ., Raleigh, N. C. 27607

Johnson, Wiley C., Dept. of Agronomy & Soils, Auburn University, Auburn, Ala. 36830

Jones, Jack E., Dept. Agronomy, Louisiana State Univ., Baton Rouge, La. 70803

Jones, U. S., Dept. Agronomy and Soils, Clemson Univ., Agr. Expt. Sta., Clemson, S. C. 29631

Kennamer, Homer, G., Jr., Fiber Technology Div., Inst. Textile Technology, Charlottesville, Va. 22904

King, Frank P., Georgia Coastal Plain Expt. Sta., Tifton, Ga. 31794

McDow, John J., Agr. Engin. Dept., Agr. Expt. Sta., Univ. of Tenn., P. O. Box 1071, Knoxville, Tenn. 37901

Mikell, John J., Agr. Expt. Sta., Louisiana State Univ., P. O. Drawer E, Univ. Sta., Baton Rouge, La. 70803

Miller, Philip A., Dept. Crop Sciences, North Carolina State Univ., P. O. Box 5155, Raleigh, N. C. 27607.

Miravalle, Robert J., National Cottonseed Products Assoc., Inc., P. O. Box 12023, Memphis, Tenn. 38112

Moore, Vernon P., U.S. Cotton Ginning Research Lab., Leland, Miss. 38756

Neely, J. W., Plant Breeding, Coker's Pedigreed Seed Co., Hartsville, S. C. 29550

Neufeld, C. H. Harry, Southeastern Agricultural Research Lab., ARS, USDA, Beecham Office Bldg., P. O. Box 5677, Athens, Ga. 30604

Porter, Walter K., Jr., Agr. Expt. Sta., Mississippi State Univ., State College, Miss. 39762

Rawls, Henry R., Gulf South Research Inst., P. O. Box 26500, New Orleans, La. 70126

Roussel, John S., Agr. Expt. Sta., Louisiana State Univ., Drawer E, Univ. Sta., Baton Rouge, La. 70803

Senti, Frederic R., NCIUR, ARS, USDA, Room 309, Bldg. A., Washington, D. C. 20250

Sites, John W., Univ. Florida, Gainesville, Fla. 32601

Stiver, E. N., Rogers Delinted Cottonseed Co., Box 1340, Waco, Tex. 76703

Strickland, P. L., Jr., Agricultural Economics, Oklahoma State Univ., Stillwater, Okla. 74074

Verhalen, Laval M., Agronomy Dept., Oklahoma State Univ., Stillwater, Okla. 74074

Waddle, B. A., Dept. Agronomy, Agr. Expt. Sta., Univ. Arkansas, Fayetteville, Ark. 72701

Watson, Walter, Ferris Watson Seed Co., Box 489, Garland, Tex. 75040

Weaver, J. W., Univ. of Delaware, P. O. Box 274, Fed. Sta., Newark, Del. 19711

Wilson, Coyt., Agr. Expt. Sta., Virginia Polytechnic Inst., Blacksburg, Va. 24061

Worner, Ruby K., 3915 St. Charles Ave., New Orleans, La. 70115

ATTENDANCE OF PERSONNEL FROM SOUTHERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

Arthur, Jett C., Jr., Cotton Chemical Reactions Laboratory

Benerito, Ruth R., Cotton Chemical Reactions Laboratory

Beninate, John V., Cotton Finishes Laboratory

Berardi, Leah C., Oilseed Crops Laboratory

Betrabet, S. M., Cotton Physical Properties Laboratory

Creely, Joseph J., Cotton Physical Properties Laboratory

Decossas, Kenneth M., Engineering and Development Laboratory

Dupuy, Harold P., Oilseed Crops Laboratory

Fiori, Louis A., Cotton Mechanical Laboratory

Fisher, C. H., Director of Division

Frampton, Vernon L., Oilseed Crops Laboratory

Gardner, Homer K., Jr., Engineering and Development Laboratory

Goldblatt, Leo A., Oilseed Crops Laboratory

Graham, Clarence O., Cotton Mechanical Laboratory

Grant, James N., Cotton Physical Properties Laboratory

Guthrie, John D., Cotton Chemical Reactions Laboratory

Hennessey, Glen Rae, Director's Office

Hoffpauir, Carroll L., Assistant Director, Program Development

Jones, Marie A., Director's Office

Keating, Esmond J., Engineering and Development Laboratory

Kingsbery, Emery C., Cotton Mechanical Laboratory

Knoepfler, Nestor B., Engineering and Development Laboratory

Koenig, Paul A., Engineering and Development Laboratory

Kopacz, B. M., Director's Office

Kyame, George J., Cotton Mechanical Laboratory

Lambou, Madeline G., Engineering and Development Laboratory

Lofton, John T., Cotton Mechanical Laboratory

Markezich, A. R., Cotton Physical Properties Laboratory

Martin, Lawrence F., Cotton Chemical Reactions Laboratory

Martinez, Wilda H., Oilseed Crops Labortory

Mazzeno, Laurence W., Jr., Director's Office

McKelvey, John B., Cotton Chemical Reactions Laboratory

Mottern, Hugh H., Engineering and Development Laboratory

Murphy, Alton L., Cotton Chemical Reactions Laboratory

Nelson, Mary L., Cotton Physical Properties Laboratory

O'Connor, Robert T., Cotton Physical Properties Laboratory

Persell, Ralph M., Assistant Director, Program Appraisal

Pominski, Joseph, Engineering and Development Laboratory

Reinhardt, Robert M., Cotton Finishes Laboratory

Rollins, Mary L., Cotton Physical Properties Laboratory

Rowland, Stanley P., Cotton Chemical Reactions Laboratory

Ruppenicker, George F., Jr., Cotton Mechanical Laboratory

Rusca, Ralph A., Cotton Mechanical Laboratory

St. Mard, Hubert H., Cotton Finishes Laboratory

Soniat, Margaret B., Director's Office

Spadaro, James J., Engineering and Development Laboratory

Stansbury, Mack F.; Director's Office

Tripp, Verne W., Cotton Physical Properties Laboratory

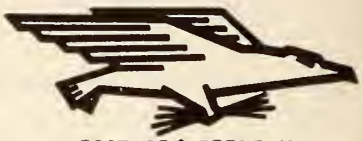
Vix, Henry L. E., Engineering and Development Laboratory

Welch, Clark M., Cotton Chemical Reactions Laboratory

Wojcik, Bruno H., Assistant Director, Industrial Development

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOUTHERN UTILIZATION RESEARCH & DEVELOPMENT DIVISION
P. O. BOX 19687
NEW ORLEANS, LOUISIANA 70119

OFFICIAL BUSINESS



POSTAGE & FEES PAID
United States Department of Agriculture